MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 116 No. 2 1956

ANNUAL REPORT OF THE COUNCIL

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NOTICE TO AUTHORS

1. *Communications.*—Papers must be communicated to the Society by a Fellow. They should be accompanied by a summary at the *beginning* of the paper conveying briefly the content of the paper, and drawing attention to important new information and to the main conclusions. The summary should be intelligible in itself, without reference to the paper, to a reader with some knowledge of the subject; it should not normally exceed 200 words in length. **Authors are requested to submit MSS. in duplicate. These should be typed using double spacing and leaving a margin of not less than one inch on the left-hand side. Corrections to the MSS. should be made in the text and not in the margin.** Unless a paper reaches the Secretaries more than seven days before a Council meeting it will not normally be considered at that meeting. By Council decision, MSS. of accepted papers are retained by the Society for one year after publication; unless their return is then requested by the author, they are destroyed.

2. *Presentation.*—Authors are allowed considerable latitude, but they are requested to follow the general style and arrangement of *Monthly Notices*. References to literature should be given in the standard form, including a date, for printing either as footnotes or in a numbered list at the end of the paper. Each reference should give the **name and initials** of the author cited, irrespective of the occurrence of the name in the text (some latitude being permissible, however, in the case of an author referring to his own work). The following examples indicate the style of reference appropriate for a paper and a book, respectively:—

A. Corlin, *Zs. f. Astrophys.*, **15**, 239, 1938.
H. Jeffreys, *Theory of Probability*, 2nd edn., section 5.45, p. 258, Oxford, 1948.

Alternatively, the Harvard reference system may be used.

3. *Notation.*—For technical astronomical terms, authors should conform closely to the recommendations of Commission 3 of the International Astronomical Union (*Trans. I.A.U.*, Vol. VI, p. 345, 1938). Council has decided to adopt the I.A.U. 3-letter abbreviations for constellations where contraction is desirable (Vol. IV, p. 221, 1932). In general matters, authors should follow the recommendations in *Symbols, Signs and Abbreviations* (London: Royal Society, 1951) except where these conflict with I.A.U. practice.

4. *Diagrams.*—**These should be designed to appear upright on the page, drawn about twice the size required in print and prepared for direct photographic reproduction except for the lettering, which should be inserted in pencil. Legends should be given in the manuscript indicating where in the text the figure should appear.** Blocks are retained by the Society for 10 years; unless the author requires them before the end of this period they are then destroyed.

5. *Tables.*—**These should be arranged so that they can be printed upright on the page.**

6. *Proofs.*—Costs of alteration exceeding 5 per cent of composition must be borne by the author. Fellows are warned that such costs have risen sharply in recent years, and it is in their own and the Society's interests to seek the maximum conciseness and simplification of symbols and equations consistent with clarity.

7. ***Revised Manuscripts.***—When papers are submitted in revised form it is especially requested that they be accompanied by the original MSS.

Reading of Papers at Meetings

8. When submitting papers authors are requested to indicate whether they will be willing and able to read the paper at the next or some subsequent meeting, and approximately how long they would like to be allotted for speaking.

9. Postcards giving the programme of each meeting are issued some days before the meeting concerned. Fellows wishing to receive such cards whether for Ordinary Meetings or for the Geophysical Discussions or both should notify the Assistant Secretary.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 116 No. 2

ANNIVERSARY MEETING OF 1956 FEBRUARY 10

Professor Sir Harold Jeffreys, President, in the Chair

The election by the Council of the following Fellows was duly confirmed :—

Sheila Anne Boulter, 66 Westwood Road, Bemerton Heath, Salisbury, Wiltshire (proposed by N. J. Goodman);

Frederick James Brown, 57 Weirdale Avenue, Whetstone, London, N.20 (proposed by F. W. Cousins);

James H. Paton, 3 St. Paul's Churchyard, London, E.C.4 (proposed by A. Hunter); and

Wolfgang Rindler, 10A Belsize Park Gardens, London, N.W.3 (proposed by G. J. Whitrow).

The election by the Council of the following Junior Members was duly confirmed :—

Alan Burgess, 26 Hadfield Street, Oldham, Lancs. (proposed by M. J. Seaton); and

Ron Ariel Javitch, 1589 McGregor Street, Montreal, 25, Province of Quebec, Canada (proposed by J. Hargreaves).

Ninety-six presents were announced as having been received since the last meeting.

The President gave an address (see p. 229) on the award of the Gold Medal to Professor Thomas George Cowling, F.R.S., to whom the Medal was then presented.

The President then delivered his address on " The Earth's thermal history " (see p. 231).

ANNUAL GENERAL MEETING OF 1956 FEBRUARY 10

Professor Sir Harold Jeffreys, President, in the Chair

The Minutes of the preceding Annual General Meeting were read, confirmed and signed.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year.

The Treasurer gave a brief explanation of the accounts and a survey of the Society's financial position. He pointed out that, despite a steady rise in the Society's income from various sources, deficits on Revenue Account of £553 and £843 were sustained in 1954 and 1955 respectively owing to more steeply rising expenditure; and a further deficit in 1956 seemed inevitable.

The Treasurer then proposed on behalf of the Council the adoption of the following amended Bye-Law 22 with effect from 1957 January 1 :—

> 22. The contribution of each Fellow shall, for the first year, be six guineas or four guineas, according to the month in which he may have been elected (viz. two guineas in all cases as an admission fee, and four guineas as the first year's contribution, if such election has taken place in the month of January, February, March, April, May or June; but only two guineas as the first year's contribution if such election has taken place in the month of October, November or December), payable at the time of his election; and four guineas for every subsequent year; such subsequent contributions to become due and be payable in advance on the first day of January in every subsequent year. In the event of a former Fellow seeking re-election, or of a former Junior Member seeking election as a Fellow, the Council may, if it thinks fit, waive the admission fee normally payable, it being understood that in all such cases the individual concerned must be formally proposed and submitted for election as provided in Bye-laws 13 to 20, apart from the payment of the admission fee.

The Treasurer also proposed the adoption of the following amended Bye-Law 23 with immediate effect :—

> 23. Any Fellow may at his entrance compound for his annual contributions, exclusive of his admission fee, by the payment of a composition fee of one hundred guineas less one guinea for each year of age (on the first day of January in the year of entrance) in excess of thirty; or he may at any time afterwards (all sums then due having been paid) compound for his subsequent annual contributions, in which case the payment shall be the composition fee as calculated according to this Bye-law for the date of entrance, reduced by one and one-half guineas for each year of Fellowship with a minimum payment of ten guineas.

After a short discussion Bye-Laws 22 and 23, amended as above, were adopted.

The Report of the Honorary Auditors was read (see p. 133).

A vote of thanks to the Honorary Auditors of the Treasurer's accounts for 1955 was proposed and carried unanimously.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Honorary Auditors and the President's Address.

The Scrutineers reported to the President the result of the ballot, and the names of the Officers and Council elected for the ensuing year were read to the Meeting. (The list of names is given on p. 239).

The thanks of the Society were given to the retiring Vice-President (Professor H. H. Plaskett), Secretary (Dr A. Hunter) and other members of Council.

The thanks of the Meeting were given to the Scrutineers of the ballot.

The Meeting then adjourned.

REPORT OF THE COUNCIL TO THE HUNDRED AND THIRTY-SIXTH ANNUAL GENERAL MEETING OF THE SOCIETY

This Report refers to the calendar year 1955

1. *Membership.*—Once again it is pleasant to record a small but heartening increase in membership (see the Table on p. 140). Full-term Junior Members continue to apply for Fellowship at a satisfactory rate, but the number of new applicants for junior membership falls short of what might be expected from the growing interest in astronomy amongst the general public. Fellows who are in a position to point out to young people the advantages of entering the Society by this means are urged to do so.

The Society has lost by death the following Associate :

Eugène Delporte

and the following Fellows :

Mark Bennett
Goldwin Howland Biggar
Cecil Mayhew Charlotti Bone
James Bootherstone
Herbert Chatley
Lord Cooper
Edward James Cope
David Yule Devine
Percy William Glover
William Michael Herbert Greaves
William Bradshaw Housman
Joseph Aldridge Holden
Benjamin Hoyle
Ross W. Marriott
Francis McClean
Paul A. McNally
Peter Yorke Millns
Francis Croten Molesworth
John Robert Pikett
Thomas Royds
Alexander Durie Russell
Albert George Shrimpton
Thomas Silcock

Obituary notices of some of these appear on pp. 143–161, together with some others held over from the last report.

2. *Finance.*—Last year's report mentioned that the Council was considering the advisability of turning to investment in equities as a partial protection against the consequences of mounting inflation. Such stocks, unlike gilt-edged, tend to maintain their real values during periods of inflation, and though the risk of capital loss is of course greater this can be minimized by suitably spreading investments, and is to some extent compensated by a rather higher yield. After taking expert advice the Council decided early in 1955 to reinvest, as opportunity offers, not more than two-thirds of the General Fund in equities, retaining the remainder in trustee securities. A large part of this programme had been carried through before market trends in the later part of the year made it advisable to call a temporary halt to the operation.

During the year the Society has received two legacies : one of £200 from S. I. Luck and another of £10 from E. J. Cope. Fellows will also be gratified

to learn that covenanted donations from compounders amount to £50. The Society owes a special debt of gratitude to our Fellow, Mr Jack Miller, who has followed his previous generous donation of the Palomar Sky Atlas and a cabinet to receive it by a special covenanted benefaction of £100 per annum. The advantage of covenanting for contributions is that their value to the Society is thereby almost doubled and those Fellows who have not already covenanted are again urged to do so. This year the Royal Society has allocated to us £1000 from the Parliamentary Grant-in-Aid for Scientific Publications, an increase of £200. Notwithstanding this welcome state of affairs, the accounts show a deficit on the year's working of £843. This is mainly attributable to a larger printing bill and to the cost of maintenance, including the provision of new benches in the Meeting Room.

Apart from investment income the two main sources of the Society's revenue are the contributions of Fellows and the receipts from the sale of publications. In order to maintain and possibly increase this sale it is essential to preserve a high standard in the quality of our publications. In order to attract papers of high merit it is necessary to keep the interval between acceptance and publication as short as possible. To this end the Council has found it advisable to appoint an Editorial Superintendent and here the Society has been fortunate in obtaining the services of Mr E. C. Rubidge, who now becomes the senior full-time employee of the Society. To meet the additional expense it was proposed to rely on the increased income expected, and in part already realized, from the Society's re-investment programme mentioned above, and on an increase in the price of our publications. Unfortunately we now find ourselves faced with stock market conditions unfavourable at present for further substantial changes in investment, with an increase in printing charges, which already absorbs about half our revenue, and with an increase in postage rates which will almost double the already high cost of distributing our publications through the post. There is therefore no alternative to an increase of one guinea in the rate of contribution from 1957 January 1. Motions to effect this and to make a corresponding increase in the composition fee are before the Meeting. If they are approved, forms for supplementary covenants and supplementary Banker's orders will be issued during the coming year. It is confidently believed that Fellows will appreciate the cogent reasons for the above changes and will reflect that the new annual contribution is only double the pre-war one, a very moderate increase by today's standards.

For many years the Treasurer's accounts have been audited by Messrs Sharp, Parsons & Co. In deciding to make a change of professional auditors as from the 1956 financial year, the Council was influenced by no dissatisfaction with the services of Messrs Sharp, Parsons, but by the prospect of real advantage in employing a firm which audits the accounts of a considerable number of other scientific and learned societies. Messrs W. B. Keen & Co. have a wide experience of the special problems which face the Society in common with our neighbours in Burlington House and have, with Messrs Sharp, Parsons' full concurrence, agreed to audit our accounts in future. The thanks of the Society have been conveyed to the latter firm for their past services.

3. *Meetings.*—In addition to the customary eight ordinary meetings and five Geophysical Discussions held during the year at Burlington House, the

Society met in Glasgow on September 7 and 8 at the invitation of the University of Glasgow and the Glasgow Astronomical Society. The meetings, and the excursions arranged by the local secretary, Dr M. W. Ovenden, were well attended; and a large audience heard Professor Otto Struve deliver a public lecture on the Evolution of the Stars. The thanks of the Society have been expressed to our hosts, Professor W. M. Smart and Dr T. R. Tannahill, to Dr Ovenden and Professor Struve and to many others who contributed to the success of the occasion.

Delegates to the International Astronomical Union in London prior to the Dublin General Assembly were entertained by the Society at a Conversazione at Burlington House on August 23. During the evening the President presented to Professor H. C. van de Hulst his Eddington Medal, and the opportunity was also taken to present to Professor F. J. M. Stratton a token copy of *Vistas in Astronomy*, to which many of those present, and many other astronomers, had contributed articles in celebration of his seventieth birthday.

4. *Publications.*—During the year the Society published and distributed the following :

Monthly Notices, Vol. **114,** Nos. 4, 5, 6; Vol. **115,** No. 1.
Memoirs, Vol. **67,** Part 2.
General Index, 1932–50.

The measures taken to speed this disappointingly slow rate of publication have been outlined in Section 2 above. It is hoped that with a full-time paid servant of the Society in charge of publications a regular schedule of editing and proof-reading will eventually be established which, in addition to reducing direct delay, will enable the printers to give higher priority to the Society's work than is possible at present.

A further increase of 10 per cent in the cost of printing was imposed in May, and at the end of the report year it was clear that a still bigger rise was inevitable in 1956. The cumulative effect of recent increases is now so serious that the Council has been forced to increase the prices charged to subscribers by 25 per cent. It has further been decided to establish a sliding scale of charges for back numbers, so that the return on sales of volumes long out of date will be better related to the current cost of printing than is the nominal price.

5. *Awards.*—The Council awarded the Gold Medal for 1955 to Professor Dirk Brouwer for his outstanding contributions to celestial mechanics. Professor Brouwer delivered the George Darwin Lecture on " The Motions of the Outer Planets " at the April meeting, when the President presented the Medal to him at a ceremony recorded by the B.B.C. and subsequently broadcast to the U.S.A.

The Eddington Medal was awarded to Professor H. C. van de Hulst for his prediction of the 21-centimetre line radiation of neutral hydrogen and for his share in its detection and observation, and in the theoretical interpretation of the observations.

Professor D. H. Menzel was elected an Associate during the year.

The Council has discussed the position of eminent foreign geophysicists vis-a-vis the Associateship of the Society. Bye-law 27, if construed narrowly,

would appear to restrict this honour to persons " eminent in the science of Astronomy ", but the Council feels itself justified in interpreting the word Astronomy here as including parts of Geophysics. In its view, therefore, no bar exists to the election of geophysicists to Associateship, and it has invited the Geophysical Committee to submit nominations for consideration along with purely astronomical candidates, at the April meeting of the Council each year.

6. *Premises.*—The Ministry of Works having drawn attention to the fire hazard from ageing flexible leads to pendent lamps, these were renewed throughout the building during the recess. Decorations were also carried out in the Upper Library and in the lumber room on the top floor.

The extinction of all hope for early accommodation in a new Science Centre has convinced the Council that the seating in the Meeting Room must be renewed. With every indication that prices will continue to rise, there was no motive for further delay and an order has been placed with a firm that submitted a suitable design and completed a prototype bench to the satisfaction of the House Committee. The new benches will be installed before the Annual General Meeting.

7. *Isaac Newton Observatory.*—The Isaac Newton Telescope Committee met early in 1956 and decided that the telescope should be a parabolic reflector. The Committee then decided to appoint a small Executive, with the object of speeding up the design stages. This Executive has had several meetings and it is hoped that a specification will be drawn up shortly.

8. *Miscellaneous.*—Miss E. M. Stanley, Junior Assistant, resigned in May and was succeeded later in the year by Miss M. C. Woodburne.

It is a pleasure to record the gift from Sir Eric Miller of a manuscript letter from William Herschel to Sir Joseph Banks, dated 1781 November 19, describing his discovery of the new planet Uranus. The document formed the basis of Banks' address on the award of the Copley Medal to Herschel. It created a good deal of interest when it was shown at the August conversazione, and its text will appear in *Occasional Notes* No. 18.

The Society's help was enlisted late in 1954 in efforts to preserve Carr House, near Preston, believed to be the house from which Jeremiah Horrocks observed the 1639 transit of Venus. This house, though scheduled as of historic interest, had been condemmed as unfit for human habitation. Negotiations with the owner's agent made it quite clear that the cost of putting the house into tenantable repair would be prohibitive, and in the circumstances it was decided not to oppose the Lancashire Planning Officer's advice to the Minister of Health that the local authority be allowed to demolish it. Photographs of the house and of the window from which the celebrated observation is believed to have been made have been added to the Society's collection.

The first section of the National Geographic Society—Palomar Observatory Sky Atlas has been delivered and is now housed in the handsome hardwood cabinet designed to hold the whole Atlas when complete. Atlas and cabinet, it will be recalled, are the generous gift of Mr Jack Miller.

Fellows will have noted with pleasure the award of the M.B.E. to Miss E. Wadsworth, lately Assistant Secretary and then Librarian to the Society.

Representatives of the Society were appointed during the year as follows:

on the Board of Management of the Isaac Newton Observatory,
Sir Harold Spencer Jones;
on the Board of Visitors of the Royal Greenwich Observatory,
Professor H. Bondi.

Professor W. M. Smart represented the Society at the memorial service to the late Professor W. M. H. Greaves.

REPORT OF THE HONORARY AUDITORS FOR THE YEAR 1955

We have examined the professionally audited accounts of the Society and have checked the official list of Fellows against the subscriptions received. We note that the membership continues to increase.

We have examined the premises of the Society and note with satisfaction :

(1) The general cleanliness and well-kept appearance throughout.

(2) The continued progress made by the Librarian in improving the card indexes and labelling all sections clearly.

(3) The redecoration of the Upper Library and Lumber Room.

(4) The installation in the Main Library of a periodicals rack, a gift from the Chemical Society.

(5) The installation of a beautiful oak chart-case, a gift from Mr Jack Miller, to be used for storing the Palomar Sky Atlas.

(6) The installation of new bench seating in the Meeting Room.

(7) The renewal of certain sections of the electric lighting circuits.

The following items are considered to be less satisfactory :

(1) The overfilled condition of the chart case in the Main Library.

(2) The untidy condition of the Strong Room.

(3) The unsatisfactory condition of the Instrument Store.

We recommend that the Lumber Room be emptied of packing-cases and that it be used to contain the Palomar Sky Atlas and the various maps, charts and photographs at present most unsatisfactorily crushed into inadequate space. We also recommend that attention be given to the Instrument Store and Strong Room.

We wish to acknowledge with gratitude the great deal of assistance given us by the Assistant Secretary in providing the information that we required.

E. A. WHITAKER
M. J. SEATON

Dr. *General Fund Revenue Account*

1954 £		£ s. d.	£ s. d.
	To Salaries and Wages, including Pension Premiums and		
2,110	National Insurance		1,824 1 9
60	,, Insurance and Telephone		75 5 9
	,, Printing etc.		
	Monthly Notices, Vol. 114, No. 6	418 17 5	
	,, ,, Vol. 115, Nos. 1–4	2,550 0 0	
	Geophysical Supplement, Vol. 7, Nos. 2 and 3 ...	421 10 1	
	Occasional Notes, Vol. 3, No. 18	286 14 5	
	Memoirs, Vol. 67, Parts 2 and 3	668 18 2	
	Index	100 0 0	
	Paper Supply	910 12 5	
	Miscellaneous printing and carriage	281 18 4	
5,209		5,638 10 10	
	Less Amount received for 1955 from the Parliamentary Grant-in-Aid for Scientific Publications through the		
800	Royal Society	1,000 0 0	
4,409			4,638 10 10
242	,, Posting and Packing		282 8 11
	,, *General Expenses* :—		
	Stationery and Office Expenses	98 10 7	
	Lighting and Heating	208 3 6	
	Travelling Expenses	9 14 11	
	Subscriptions to National Central Library and A.S.L.I.B.	4 4 0	
	Accountants' Fees	73 10 0	
	Gold Medal	14 10 0	
	Furniture and Fittings, including repairs	47 7 0	
	I.A.U. Telegram Service	11 1 2	
	House Expenses	183 9 7	
	Meeting Expenses	58 14 3	
	Library Expenses	32 11 2	
	Sundries	142 0 1	
745			883 16 3
190	,, Block Subscription to *The Observatory*		190 0 0
7	,, Purchase of Books		14 4 10
300	,, Reserve for Repairs		600 0 0
198	,, Binding of Periodicals, etc.		186 14 6
249	,, Reproduction of Photographic Slides and Prints		293 5 2
—	,, Films, Hire and Expenses		22 7 10
6	,, Reprint Expenses		— — —
3	,, Glasgow Meeting Expenses		1 10 11
—	,, Conversazione Expenses		55 1 9
£8,519			£9,067 8 6

One Year to 1955 December 31 *Cr.*

1954 £		£ s. d.	£ s. d.	£ s. d.
	By *Amounts received from Fellows* :—			
	1 Annual Contribution for 1951 ...	3 3 0		
	1 Annual Contribution for 1952 ...	3 3 0		
	2 Partial Annual Contributions for 1953	3 3 0		
	2 Annual Contributions for 1953 ...	6 6 0		
	4 Partial Annual Contributions for 1954	6 16 0		
	23 Annual Contributions for 1954 ...	72 9 0		
	19 Admission Fees for 1954	39 18 0		
	18 First Contributions for 1954	18 18 0		
	1 Junior Member's Annual Contribution for 1954	1 1 0		
	807 Annual Contributions for 1955 ...	2,542 1 0		
	4 Partial Annual Contributions for 1955	6 5 0		
	6 Institutional Membership Fees for 1955	18 18 0		
	26 Junior Members' Annual Contributions for 1955	27 6 0		
	41 Admission Fees for 1955	86 2 0		
	53 First Annual Contributions for 1955 ...	127 1 0		
2,900			2,962 10 0	
443	,, Income Tax recovered on those under Covenant		471 9 6	
	,, *Composition Fees* :—			
	Reduced Fees...	11 0 6		
	Less Transferred to Reserve Account...	11 0 6		
	Add Amount brought to Credit for the year	155 6 6		
165			155 6 6	
	,, Special donations from Compounders		50 8 6	
	Mr. Jack Miller's Benefaction		100 0 0	
3,508				3,739 14 6
	,, Interest and Dividends received (gross) ...		1,197 0 6	
	,, Interest received on Bank Deposit Accounts ...		128 14 11	
1,238				1,325 15 5
	,, Sales of Publications, Photographs and Miscellaneous Receipts for the year :			
	Monthly Notices, Vol. 113 and earlier ...		359 9 11	
	,, ,, Vol. 114		45 3 2	
	,, ,, Vol. 115		1,272 4 10	
	Geophysical Supplement		134 0 2	
	Memoirs, Occasional Notes and Miscellaneous Reprints		229 19 7	
			445 12 2	
	Palomar Slides and Prints		177 11 10	
	R.A.S. Slides and Prints		134 12 0	
	Hire of Films		50 5 11	
	British Astronomical Association		168 0 0	
	London Mathematical Society		40 0 0	
	Sale of Schmidt Camera		100 0 0	
	Sundries		1 9 0	
3,220				3,158 8 7
7,966				8,223 18 6
553	,, Deficit for the year 1955			843 10 0
£8,519				*£9,067 8 6*

Balance Sheet

	£ s. d.	£ s. d.	£ s. d.
General Fund :—			
As at 1954 December 31	29,795 10 4		
Add E. J. Cope Legacy	10 0 0		
S. J. Luck Bequest	200 0 0		
Pension Fund	101 12 6		
		30,107 2 10	
Deduct losses, less profit, on sale of investments ...	905 15 0		
Excess of Expenditure over Income 1955 ...	843 10 0		
		1,749 5 0	
			28,357 17 10
Trust Funds :—			
Capital as at 1954 December 31		7,459 10 2	
Income Balances at 1955 December 31		1,896 6 11	
Income Tax on Trust Funds, 1955 April–December, not yet refunded		18 9 0	
			9,374 6 1
Arthur Stanley Eddington Commemoration Fund :—			
As at 1954 December 31		409 2 6	
Income Balance at 1955 December 31		55 0 6	
			464 3 0
Mr. Jack Miller's Gift—Palomar Sky Atlas Fund :—			
As at 1954 December 31	100 0 0		
Received in 1955	57 10 0		
Income Tax not yet refunded	42 10 0		
		200 0 0	
Less First payments on Sky Atlas		94 8 9	
			105 11 3
Repairs and Maintenance Reserve :—			
As at 1954 December 31	599 7 4		
Add Set aside 1955	600 0 0		
		1,199 7 4	
Less Expenditure 1955 (including £500 on account of new seating)		660 0 0	
			539 7 4
Sale of Discarded Books Fund :—			
As at 1954 December 31	855 8 6		
Add Sales 1955	1,436 5 0		
Interest 1955	43 7 1		
		2,335 0 7	
Less Expenditure 1955		1 11 6	
			2,333 9 1
Composition Fees Reserve Fund :—			
As at 1954 December 31	2,577 14 9		
Received in 1955	11 0 6		
		2,588 15 3	
Less 6 per cent transferred to Revenue Account ...		155 6 6	
			2,433 8 9
Staff Pension Fund :—			
As at 1954 December 31	622 5 9		
Add Interest 1955	15 11 0		
		637 16 9	
Less Pension paid		67 12 0	
			570 4 9
Benevolent Fund :—			
Balance at 1955 December 31			23 9 4
Amounts received in Advance :—			
Contributions :			
1956 paid in 1953	6 6 0		
1957 paid in 1953	3 3 0		
1958 paid in 1953	3 3 0		
1956 paid in 1954	6 6 0		
1956 paid in 1955	143 17 0		
1957 paid in 1955	6 6 0		
1958 paid in 1955	3 3 0		
after 1958 paid in 1955	19 10 0		
		191 14 0	
Publications, 1955		127 14 0	
			319 8 0
Sundry Creditors for Accounts due but not presented (including provision for printing publications for 1955 and binding periodicals, not yet completed) ...			4,877 18 1
			£49,399 3 6

To the Fellows of THE ROYAL ASTRONOMICAL SOCIETY

We have examined the above Balance Sheet with the Books and Vouchers relating thereto and have obtained all the explanations given to us.

We have verified the Securities representing the Investments and have found them to be in order.

SUFFOLK HOUSE,
5 LAURENCE POUNTNEY HILL, LONDON, E.C.4.
1956 February 9.

1955 *December* 31

	£ s. d.	£ s. d.	£ s. d.
Investments :—			
General Fund, valued as at 1922 December 29 or subsequent cost		29,799 16 6	
Trust Funds, valued at cost		7,448 2 2	
(Market value 1955 December 31, £34,098)			37,247 18 8
Debtors :—			
General		282 14 8	
Income Tax Recoverable :			
General Fund		185 7 5	
Trust Funds		18 9 0	
Palomar Sky Atlas Fund		42 10 0	
Payments under Covenant		42 10 0	
			571 11 1
Deposits at Savings Banks :—			
General Fund	6,688 6 11		
Trust Funds	873 4 2		
		7,561 11 1	
Balance on Current Account at Bank and Cash in Hand :—			
General Fund	2,983 11 11		
Trust Funds	1,034 10 9		
		4,018 2 8	
			11,579 13 9

Note.—Contributions unpaid at 1955 December 31, and amounting to £202 13s. 0d., have not been included in this Balance Sheet.

£49,399 3 6

and certify it to be correctly drawn up therefrom and in accordance with the information and in order.

SHARP, PARSONS & Co.,
Chartered Accountants.

INVESTMENTS

As at 1955 December 31

General Fund

£2000 Swansea Corporation 3½ per cent Stock.
£7386 12*s.* 9*d.* British Transport 3 per cent Guaranteed Stock, 1978/88.
£496 Consolidated 4 per cent Stock, 1957.
£1035 Agricultural Mortgage Corporation, Ltd., 4½ per cent Debenture Stock, 1961–91.
£700 Birmingham Corporation 3 per cent Stock, 1947.
£2280 5*s.* 3*d.* War Loan 3½ per cent Inscribed Stock.
£1156 1*s.* 5*d.* Metropolitan Water 3 per cent "B" Stock.
£695 16*s.* 0*d.* Conversion Loan 3½ per cent, 1961.
£3718 British Gas 3 per cent Guaranteed Stock, 1990–95.
£78 1*s.* 3*d.* War Loan 3½ per cent Registered Stock.
£2009 5*s.* 3*d.* Hull Corporation 3¾ per cent Redeemable Stock, 1973–75.
£500 Australian 3 per cent Loan, 1972/74.
1800 British Motor Corporation, Ltd., Ordinary 5/- Shares.
250 National Canning Co. Ltd., Ordinary £1 Shares.
£5000 British Electricity 4¼ per cent Guaranteed Stock, 1974/79.
£6073 9*s.* 0*d.* Treasury 3 per cent Stock.
£500 Courtaulds Ltd. £1 Stock Units.
400 Porritts and Spencer, Ltd., Ordinary £1 Shares.
600 P. & O. Steam Navigation Co., Deferred Ordinary £1 Shares.
£300 Chloride & Electrical Storage Co. Ltd., "A" Ordinary £1 Stock Units.
700 Dunlop Rubber Co., Ltd. 10/- Ordinary Stock Units.

Trust Funds

£1004 Consolidated 4 per cent Stock, 1947.
£965 Agricultural Mortgage Corporation, Ltd., 4½ per cent Debenture Stock, 1961–91.
£491 10*s.* 0*d.* War Loan 3½ per cent Inscribed Stock.
£1160 16*s.* 3*d.* War Loan 3½ per cent Inscribed Stock.
£542 18*s.* 2*d.* Savings Bonds 3 per cent, 1960/1970 (Holding "B").
£1122 19*s.* 6*d.* Savings Bonds 3 per cent, 1960/1970 (Holding "C").
£1471 4*s.* 0*d.* Savings Bonds 3 per cent, 1955/1965.
£375 Savings Bonds 3 per cent 1955/1965.
£100 Savings Bonds 3 per cent 1960/1970 (Holding "D").
£250 War Loan 3½ per cent Stock.

GIFTS AND BEQUESTS TO THE SOCIETY

Full details of the circumstances and amounts of the gifts and bequests listed below are published quinquennially, together with revenue statements concerning the Special Funds and Trust Funds. The latest statement appeared in *M.N.*, **113**, 287, 1953.

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY

The John Lee Gift (1836 and 1844)
The Lawson Bequest (1856)
The Carrington Bequest (1876)
The Lambert Bequest (1877)
The McClean Bequest (1905)
The Farrar Bequest (1906)
The Parsons Gift (1922)
The Grove-Hills Bequest (1922)
The Grove-Hills Fund (1922)
The Lindemann Bequest (1931)
The Archdeacon Potter Bequest (1933 and 1951)
The Goodridge Bequest (1936)
The Herbert Spencer Bequest (1936)
The Lindley Bequest (1937)
The Stanley Williams Bequest (1939)
The E. W. Brown Bequest (1939)
The Plummer Bequest (1946)
The Carder-Davies Bequest (1948)
The M. A. Nadarov Bequest (1950)
The W. H. Owston Bequest (1951)
The Rev. Harold Pain Bequest (1953)

SPECIAL FUNDS

The Archdeacon Potter Fund (1933 and 1951)
The Victor Nadarov Fund (1950)
The Arthur Stanley Eddington Commemoration Fund (1948)
Benevolent Fund (1950)
Palomar Sky Atlas Fund (1954)

TRUST FUNDS

The Lee and Janson Fund (1834 and 1879)
The Turnor Fund and the Horrocks Memorial Fund (1853 and 1876)
The Hannah Jackson (*née* Gwilt) Fund (1861)
The Harry Watson Memorial Fund (1923)
The George Darwin Lectureship Fund (1926)
The A. G. Stillhamer Trust (1937)
The E. W. Brown Trust (1939)
The Plummer Bequest (1946)

BEQUESTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY DURING 1955

Mr Edward James Cope (died 1955 April 30) £10
Mr Sidney Ivor Luck (died 1954 November 28) £200

GIFTS TO THE GENERAL FUNDS AND PROPERTY OF THE SOCIETY DURING 1955

Mr Jack Miller £100

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Fellows: Compounders	Fellows: Annual Contributors	Junior Members	Associates	Total
1955 January 1	1	6	198	870	35	51	1161
Since elected		1	...	64	4	1	70
Fellows re-elected		...	...	2	...	...	2
Junior Members elected to Fellowship ...		...	...	9	−9	...	0
Deceased 1955		...	−4	−16	...	−1	−21
Deceased before 1955, notified in 1955 ...		...	−1	−1	...	...	−2
Since compounded...		...	1	−1	...	...	0
Resigned 1955		...	...	−14	...	...	−14
Names removed		...	...	−4	...	...	−4
Names restored, previously removed presumed deceased		...	2	...	...	...	2
1956 January 1	1	7	196	909	30	51	1194

(N.B.—Fourteen Associates are also Fellows, and are therefore counted twice in the above table.)

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE PRESENTED GIFTS (OTHER THAN BY EXCHANGE) TO THE LIBRARY DURING THE YEAR 1955

Academia Nacional de Ciencias Exactas, Fisicas y Naturales, Lima
Academy of Sciences, U.S.S.R.
Association Française d'Observateurs d'Etoiles Variables
Astronomical Society of South Africa
Astronomical Society of Tasmania
Astronomische Gesellschaft
Australian Journal of Science
British Astronomical Association, New South Wales Branch
British Council
Cambridge University Press
Carnegie Institution of Washington
Cartuja Observatory
Centre National de la Recherche Scientifique
Chapman and Hall
Commissione Geodetica Italiana
Defence Research Board, Canada
The Publishers of the Encyclopaedia Britannica
Faber and Faber
Geophysical Institute of the Faculty of Science, University of Zagreb
Gollancz and Co.
Griffin and Co.
Hamburger Sternwarte
Harvard College Observatory
Imperial Chemical Industries
Indiana University, Astronomy Department
Institution of Telecommunication Engineers, India
International Astronomical Union
International Scientific Radio Union
International Union of Geodesy and Geophysics
International Union of Theoretical and Applied Mechanics
Jeremiah Horrocks Observatory
Jugoslavenska Akademia Znanosti i Umjetnosti
The Keeper of Printed Books, British Museum
Longmans, Green and Co.
McMath-Hulbert Observatory
Maria Mitchell Association
Ministry of Education, Pakistan
National Oceanographic Council
National Research Council of Canada
National Science Foundation, U.S.A.
Perkin-Elmer Corporation
Physical Society
The Editors of Physics Abstracts
The Editors of Rise Hvézd
Royal Alfred Observatory, Mauritius
Royal Meteorological Society

Science Council of Japan
The Editors of Scientific American
Skalnaté Pleso Observatory
Sociedad Astronómica de Mexico
Societas Scientiarum Fennica
The Editors of Tellus
Universidade do Porto, Faculdade de Sciências
Universitätssternwarte, Munster
University of California
Uniwersytet Marii Curii Sklodowskiej i Lublin
The Editors of Urania
The Editors of Vega
The Director Wiener Sternwarte
World Calendar Association
Yale-Columbia Southern Station
Carl Zeiss Verlag

Professor C. W. Allen
Dr G. Alter
Dr A. Armitage
Mr D. W. G. Arthur
Professor A. Dauvillier
Miss D. Davies
Professor H. Dingle
Dr M. A. Ellison
Professor K. Hujer
Dr J. Jackson
The late Mr I. O. Jones
Sir Harold Spencer Jones
Mr L. P. Lee
Professor F. C. Leonard
Dr E. H. Linfoot
Mr H. A. Lloyd
Professor A. C. B. Lovell
Mr W. J. Luyten
Mr S. L. Malurkar
Sir Eric Miller
Mr J. Miller
Mr P. A. Moore
Mr S. Ocampo
Professor A. Unsöld
Professor M. Waldmeier
Captain R. S. Webb
Dr G. J. Whitrow
Dr H. P. Wilkins

OBITUARY NOTICES

EUGÈNE JOSEPH DELPORTE was born on 1882 January 10 in Genappe, province of Brabant, Belgium. He graduated at Brussels University and in 1903 obtained the Degree of Doctor of Science with 1st class Honours in Physics and Mathematics.

In 1903, at the early age of 21, he joined the Belgian Royal Observatory as a voluntary assistant. A year later he was promoted to assistant and in 1909, after five years of work, he was appointed Assistant Astronomer, finally rising to the status of Astronomer in 1924. Twelve years later, in 1936, he was made Director and for the rest of his life he dedicated himself to the systematic observation of small planets. In 1947 he was made Honorary Director whilst he was pursuing his work in relation to the determination of the exact position of asteroids. We may recall that from 1903 to 1923 he was attached to the service of " the Meridian " and that from 1923 to 1936, when he became Director, he was Chief Astronomer of the Service of Equatorials.

During his life he obtained many academic distinctions. At the age of 46, in 1928, he was awarded the Prix Agathon De Potter by the Royal Academy of Belgium, and in 1937 he was made Member Correspondent of the Bureau of Longtitude in Paris. In 1947 he was accepted as Member Correspondent of the Science Academy of Paris; and in 1950 he was awarded the Belgian distinction of scientific " Doyen du Travail " for astronomy. He was also a member of the National Belgian Committee of Astronomy since its foundation in 1919, becoming its Vice-President in 1936, and President from 1947 until his death in 1955. Since the creation of the International Astronomical Union in Brussels in 1919 until the Dublin Congress of 1955, M Delporte attended all the International Astronomical Conferences, with only two exceptions.

He was a member of many Committees and from 1938 to 1948 he was President of a Commission whose object was the observation of planets, comets and satellites, and the determination of their positions and " ephemerides ". Several times he took part in the Congresses organised in Paris by the National Committee of French Astronomy, and he was also President of various Congresses of the French Association for the Advancement of Science. In 1946 he attended the Executive Committee of the International Astronomical Union in Copenhagen. He also took part in the Belgian Congresses of Science of 1930, 1935 and 1950. In addition he found time to be a member of numerous learned Societies connected with Astronomy in Belgium and abroad. He was Secretary-Editor of Astronomy to the Journal *Ciel et Terre* from 1909 to 1926, and from 1927 until his death he was Vice-President of the Belgian Astronomical Society. For two years, between 1920 and 1922, he directed the service of Astronomical Telegrams of the International Astronomical Union.

During his lifetime M Delporte made many observations and was responsible for the compilation of several important catalogues of stars. In 1912, in collaboration with M E. Viennet of Paris Observatory, he determined the difference in longitude between Uccle and Paris Observatories.

In 1923, as Chief of the " Equatorial Service ", he organised the investigation of small planets. He discovered several dozens of small planets, amongst which may be mentioned Amor and Adonis, which have very peculiar orbits. His name is attached to the discovery of the Comet Dutoit-Neujmin-Delporte.

In 1930 he edited two volumes for the International Astronomical Union, *Scientific Delimitation of Constellations*, with text, maps and celestial atlas. For the first time delimitation of constellations was fixed for the whole of the sky.

M Delporte was actively interested in the re-equipment of the Royal Belgian Observatory, which took place on the occasion of the Belgian Independence Centenary in 1930. The Observatory was provided with a telescope of one meter aperture, with a double astrograph of 40 cm aperture and with Askama transit circle of 19 cm aperture. He was also responsible for the transformation of the Cooke visual refractor of 38 cm of aperture, which has been provided with a Zeiss objective of 45 cm diameter. He was not only remarkable as an observer and fine scientist, but he knew how to inspire and guide young astronomers. By his unfailing enthusiasm and help he greatly contributed to ensuring the future of the Royal Belgian Observatory.

His sudden death, which occurred on 1955 October 19 at Uccle whilst examining some plates of asteroids, after almost exactly fifty-two years of work devoted to science and astronomy, is not only a great loss to Belgian astronomy, but to the whole astronomical world.

Not only will M Delporte be remembered as a keen observer, a tireless worker and a brilliant and devoted scientist and astronomer, but his memory will live on in the hearts of his colleagues and friends as a generous and unselfish man of great understanding and sensitive feelings.

He was elected an Associate of the Society on 1946 May 10.

HERBERT CHATLEY was born in London in 1885 and died on 1955 January 17.

He was a civil engineer by profession, being a D.Sc. of London University, M.I.C.E. (England) and M.I.C.E. (Ireland). In 1906 he wrote a book on *The Problems of Flight*. Two years after his marriage in 1907 to the only daughter of Mr and Mrs W. Loader Smith of Southsea, he went to China as Professor of Civil Engineering at Tanshan, a post which he occupied until 1915 when he went to Shanghai, where he remained in engineering appointments till his retirement in 1937. On the outbreak of the Second World War he was employed by the Admiralty and was concerned in the preparation of the Mulberry Harbour.

It was in China that his interest in astronomy developed and he became an authority on the history of Chinese astronomy as evidenced by the scholarly articles which he contributed to various journals. An article *Did Ancient Chinese culture come from Egypt?* which appeared in 1929 in the Journal of the North China Branch of the Royal Asiatic Society, is perhaps the first indication that he was also interested in Egyptian astronomy. Since then he has made contributions on the subject in the *Journal of Egyptian Archaeology* and the *Observatory* (*J.E.A.*, 1940, 1941, 1948/9 and *Observatory*, **62,** 100) which showed that he had made himself familiar with nearly all that has been written on the subject in modern times.

He was elected a Fellow of the Society on 1950 March 10 and he was also a Fellow of the Physical Society of London and Associate Fellow of the Royal Aeronautical Society.

Scottish astronomy owes much to the active interest of LORD COOPER OF CULROSS. Thomas Mackay Cooper was born in 1892; after a most distinguished career at George Watson's College and later at the University of Edinburgh, where he graduated with 1st Class Honours in Classics, he was called to the Scottish Bar in 1915. He subsequently held the highest legal positions in Scotland, becoming Solicitor General in 1935 and Lord Justice General of Scotland and Lord President of the Court of Session from 1947. In the years 1935–41 he was Unionist M.P. for the division of Edinburgh West.

Elected a Fellow of the Royal Society of Edinburgh in 1936, Lord Cooper later became one of its Vice-Presidents and was for many years a member of the Robert Cormack Committee of the Society.

On the Cormack Committee Lord Cooper's legal training was of great value in the administration of the Trust which amounts to a capital sum of £56,000. The interest on this bequest has been devoted since 1942 to the promotion of astronomical research; to the establishment of Fellowships; and to provision for lectures on astronomy to schools throughout Scotland. Large research projects, like the St. Andrews Schmidt-Cassegrain telescope, have been notably assisted by the Committee. The writer also remembers with pleasure the keen and informed interest which was shown by Lord Cooper during the construction in 1949 of the 10-inch Coelostat with quartz mirrors; this instrument is now on loan from the Cormack Committee for solar work at the Royal Observatory.

During an immensely active life Lord Cooper served as Chairman of innumerable public boards and inquiries, such as the Committee on Hydro-Electric Development in Scotland (1941) and the Committee of Inquiry into St. Andrews University (1949). His legal publications were extensive and he was regarded as one of the great historians of Scottish Law. He died at his home in Edinburgh on 1955 July 15.

He was elected a Fellow of the Society on 1948 February 13.

M. A. ELLISON.

"With the untimely death of WILLIAM MICHAEL HERBERT GREAVES, British astronomy has suffered a severe loss. Whilst he will be remembered chiefly for his pioneer work on stellar spectro-photometry, his contributions to dynamical astronomy and to geomagnetism were substantial.

He was always glad to serve the Society: he was a member of Council for an aggregate of 14 years being Secretary for 7 years and holding the office of President from 1947 to 1949. Always an active member of the national and international committees on which he served, his considered advice will be greatly missed."

The above resolution by the President, Council and Fellows of the Society conveyed to Mrs Greaves the feeling of loss that we had suffered by the death of the Astronomer Royal for Scotland on 1955 December 24.

He was born in Barbados, British West Indies, on 1897 September 10, the only son of the late Dr E. C. Greaves who had graduated in medicine from Edinburgh University. Educated first in a local school and at Codrington College in the West Indies, he proceeded to Cambridge in the middle of the First World War and became a scholar of St. John's College. There he gained many distinctions. He was a wrangler at the Mathematical Tripos of 1919, gaining special distinction and the Tyson Gold Medal for Astronomy.

He was awarded a Smith's Prize in 1921, became Isaac Newton Student the same year and was duly elected a Fellow of his College.

At St. John's Greaves came under the influence of H. F. Baker who, after a distinguished career as a pure mathematician, had been elected Lowndean Professor of Astronomy and Geometry, and took up investigations of the expansions which occur in celestial mechanics, from the mathematical point of view. The earliest publications of Greaves in our *Monthly Notices* were in this field, and in fact Volume **82** contains no less than four papers by him. The first dealt with the existence theorem for two families of periodic orbits near Lagrange's equilateral triangular points in the restricted problem of three bodies and the second with long period irregularities in the movement of asteroids with a mean motion nearly equal to half that of Mars. For four asteroids he determined the amplitude and period of inequalities due to the action of Mars and also of Jupiter. The other two papers were prompted by G. R. Goldsbrough's work on the influence of satellites on the form of Saturn's ring and pointed out the weakness of arguments indicating instability when only first order terms were considered.

At this period Greaves became associated with E. V. (now Sir Edward) Appleton on the solution of differential equations which arose in the theory of electrical oscillations of triode valves then becoming very important for the generation of radio waves. His knowledge of the solution of similar equations arising in astronomical problems was put to good use as indicated by several papers in the Proceedings of the Royal Society, in the Phil. Mag. and in Proc. of the Cambridge Phil. Society.

In 1923 on the suggestion of Sir Joseph Larmor arrangements were made for Isaac Newton Students to spend some time at the Royal Observatory, Greenwich, to get first hand knowledge of practical astronomy. For several months Greaves worked with C. R. Davidson and this led to two short papers in *Monthly Notices* concerning systematic errors which might arise in parallax determinations, the more important dealing with the effect of difference in colour of the parallax and comparison stars if the hour angles were more than specified amounts.

The appointment of Dr H. (now Sir Harold) Spencer Jones as H.M. Astronomer at the Cape produced a vacancy at Greenwich to which Greaves was appointed early in 1924. He continued to work principally in the department with Mr. Davidson, but he also entered into the work of other departments. His principal contributions were in the field of spectrophotometry. In 1926, an extensive programme was started to determine the " colour temperatures " of stars. The quantity actually observed in the comparison of two stars, known as the relative gradient is

$$\Delta\phi = \phi - \phi_0 = 0{\cdot}921 \times \frac{d}{d(1/\lambda)}\Delta m_\lambda$$

where Δm_λ is the difference in magnitude at wavelength λ between the stars compared. By Planck's law

$$\phi = \frac{c}{T}(1 - e^{-c/\lambda T})$$

where c is a known constant and T is the absolute temperature. It turns out that $\Delta\phi$ is nearly independent of λ. There were many difficulties to be faced in applying this formula, i.e., in determining Δm_λ. The most difficult obstacle

resulted from the poor and deteriorating conditions in the smoky, artificially illuminated, sky at Greenwich. The work involved a comparison of the intensity of the light of various wave-lengths for stars which might be well separated in the sky (60° or more). It was generally arranged that comparisons should be made when the stars were near the same altitude when the relative atmospheric absorption would be the same (or nearly the same) for the stars compared. In this way the relative gradients were determined first of all for 25 standard stars chosen amongst the brightest of spectral types A and B. In order to obtain absolute gradients (and temperatures) it was necessary to compare at least one star with a terrestrial source of known temperature. This problem was tackled by setting up an acetylene flame on the roof of the Octagon room about 600 ft from the telescope and making the observations through the same optical train apart from the Earth's atmosphere. The reddening due to the Earth's atmosphere was determined by means of standard stars at different zenith distances as nearly as possible at the same time, as this factor could not be trusted to remain constant for long.

The accurate determination of Δm_λ involved many subsidiary investigations resulting from the peculiarities of the photographic plate in its response to light of different intensities, of different wavelength and for different lengths of exposure. But all the difficulties were overcome and finally a catalogue giving the gradients for 250 stars was published—mostly the brightest early type stars but also including some later ones. An interesting result was the discovery that some early B type stars were as yellow as normal stars of type F0–F5. For the variable star δ Cephei the gradient followed closely the same curve as that of total light variation.

This work was carried out first with the old 30-inch reflector at Greenwich and later with the Yapp 36 inch. A large prism was used to produce the spectrum and this could be crossed by a grating to determine a scale for Δm. Throughout the work Greaves was assisted by C. R. Davidson in planning the observations and by E. G. Martin in work at the telescope and in measuring the plates in the microphotometer. A number of papers have been published in *Monthly Notices* and *The Observatory*; the main body of the work is given in two publications from Greenwich.

It had long been known from Greenwich records that magnetic disturbances and sunspot activity showed the same periodicity waxing and waning in an eleven year period. Greaves with H. W. Newton, who was in charge of the solar department, investigated the connection between large individual magnetic disturbances and large sunspots. Three papers by the joint authors appeared in 1928–29. First, they confirmed the statistical relationship which Maunder (1904) had established between the occurrence of great magnetic storms and the central meridian passages of large sunspots. The central meridian passage of the spot preceded the magnetic storm by 1½ days on the average; and this interval was attributed to the travel time of the storm-producing agency (a particle stream) which was assumed to issue nearly vertically from a disturbed chromospheric region. Secondly, they divided magnetic storms into two types, related to their geomagnetic effects: (*a*) great storms, mostly beginning with a "sudden commencement", which were associated with large sunspots but which showed no recurrence tendency; (*b*) lesser storms, apparently unassociated with sunspots, which showed a marked tendency to recur at 27-day intervals.

Later work has confirmed this distinction: type (*a*) is now attributed to the isolated blast of particles from a flare within the sunspot region, and type (*b*) to the long-lived stream of particles from a solar M-region. Greaves continued to take an interest in geomagnetism, was responsible for drawing a number of magnetic charts for the Admiralty and gave a most interesting address when, as President of the Society, he presented the Gold Medal to Professor Chapman for his contributions to geophysics and solar physics, and particularly to the theory of geomagnetic phenomena.

In a paper written soon after he went to Greenwich, Greaves discussed the differences which had been found for the declination of the solar apex. For this purpose he employed radial velocities and transverse velocities (from proper motions) of the same stars of types F to M. His interest in the fundamental work of the Observatory was shown by a paper in which he carried through a comparison between the right ascensions of the Second Greenwich Catalogue of Stars for 1925.0 and of the FK3. A change from an earlier Greenwich catalogue was attributed to a change in the stars used for determining azimuth and the method of observing them.

In 1938 Greaves succeeded Professor R. A. Sampson as Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh. He found at his disposal a 36-inch reflector, similar to the Yapp at Greenwich, and provided with a Hilger prism slit spectrograph. He at once formulated plans for measurement of the total intensities of the principal hydrogen and other lines in the spectra of stars of types O and B. With the assistance of E. A. Baker a microphotometer of suitable design was constructed, largely in the Observatory workshop. The microphotometer was deliberately designed as a non-recording one.

This programme had scarcely got under way when war broke out and it soon had to be temporarily abandoned not only by restrictions on night work but because the whole activity of the Observatory had to be directed to establishing a national time service. It had previously been possible to send the six-pip time signals from Edinburgh, but in the autumn of 1940 it was decided to arrange for the sending of all the rhythmic signals usually sent from Greenwich or Abinger. The apparatus was fortunately completed so that Edinburgh could take over in the difficult days of January 1941. From then till the end of the emergency Edinburgh played an important part in the transmission of signals as it was not necessary for the lines to pass through London. To enable the time to be accurately known at Edinburgh, the necessary transit observations were made there whenever possible and the results were compared with those made at Abinger. This expansion of the time service with the introduction of Quartz Clocks left no time for the small staff at Edinburgh to engage in their normal research programmes.

With the return of peace the spectrophotometric work was resumed and pressed on with vigour. The first paper giving the results obtained by the "Greaves–Baker" method was published by E. A. Baker in the new series of "Publications of the Royal Observatory, Edinburgh" with the title, *Spectrophotometric measurements of Early Type Stars—Methods of observation and results for Oe5 stars.* The second paper of the same series appeared in 1955—*Results for stars of type B1* by Greaves, Baker and Wilson.

The important novel principle used in the reduction of the microphotometer measurements was the numerical averaging of the measures of several spectra

of a star, and indeed of those of several stars of the same type. It is (or should be) well known that important results may be lost, or even erroneous ones introduced, by the graphical smoothing of data. The numerical method used at Edinburgh increased the accuracy by averaging results for a number of plates, while accidental irregularities due to the grain of the plate or other causes were minimised. Lines which were too feeble to show up on a single plate because their influence did not exceed that of the accidental irregularities could be detected in this way. R. Wilson discovered a hitherto undetected series of shallow helium lines, originating in the fifth quantum level in the spectra of Oe5 stars. One of the difficulties in determining the equivalent width of lines is due to uncertainty in the intensity of the continuum and the numerical method fixes this in a manner not subject to personal error. It is agreed that measures of equivalent widths obtained by this method are more reliable than those secured from single spectra taken with more powerful instruments, and in disclosing features common to groups of stars of similar type the method is unsurpassed. The method, however, is extremely laborious, each spectrum having been measured at about 1500 different wavelengths, and, had the computing effort not been skilfully organised and pursued by Greaves with mechanical aids, it would have been almost impracticable with the small staff available. The original programme covered about 100 stars down to magnitude 5·0, of types O and B. At the time of Greaves's death the observational part of the programme was virtually complete and the reduction of the data about half complete.

Although Greaves's own researches at Edinburgh were mostly in the fields already mentioned he was able, with an increased staff, to expand the work of the Observatory. Since quite early days observations for the determination of the solar rotation spectroscopically had been carried on. Some of the techniques of accurate spectrophotometry were now applied to the solar chromosphere and have yielded valuable results in the study of the flares and of prominences. A combined spectrohelioscope and spectrograph was designed and built for this type of work by M. A. Ellison who joined the staff in 1947. The examination of the solar spectra was greatly facilitated through the construction for Edinburgh in 1948 of a recording microphotometer of unusual design by Messrs Kipp en Zonen of Delft. This could also be employed as an actinometer for stellar photometry. Greaves's interest in solar-terrestrial relations led him to welcome Ellison's proposals for the study of the ionospheric effects of solar flares at Edinburgh and support the plans for the provision of radio equipment for this purpose.

Further plans had been laid for improving the equipment of the Observatory. A 24 16-inch Schmidt telescope, designed for stellar photometry, was erected in 1951. Treasury approval has been obtained for the construction of a new grating spectrograph for the 36-inch reflector and the installation of aluminising plant capable of coating all the mirrors of the Observatory.

As Professor of Astronomy at Edinburgh University, Greaves always took his teaching duties seriously, realising their importance for the future of Astronomy. Even although the majority of the students were in their first year he derived a great deal of satisfaction and enjoyment from this work. In 1950 he got a full time lecturer appointed. At the same time a class in astrophysics was organized, suitable for honours students in physics. This led to a closer link between the Observatory and the University.

Most of Greaves's research papers dealing with the result of observations at Greenwich and Edinburgh were written in collaboration with colleagues of whom he was the senior. In addition he prepared a considerable number of addresses and reports dealing with photometry and spectrophotometry. He acted as recorder of Section A of the British Association and prepared for the B.A. in 1939 an address on *Surface Temperatures of Stars*, printed in *The Observatory* of which he had been an Editor. To our Society he delivered as President not only the address already mentioned but others on the occasions when he presented the Gold Medal to Professors Minnaert and Lindblad. He gave a presidential address on the photometry of the continuous spectrum (1948) and earlier (1941) had prepared a Council Note on *The escape of continuous radiation from stellar atmospheres*. In 1945 he gave the Halley Lecture at Oxford on *Photometry as a weapon of astronomical research*. More recently as President of Commission 25 of the I.A.U. he prepared valuable reports on Stellar Photometry for the meetings at Rome in 1952 and Dublin in 1955. All these are valuable to anyone interested in astrophysics. As he himself wrote, they " illustrate the way in which natural knowledge is advanced by an interplay between observation and theoretical investigations."

Greaves was a tall man, rather heavily built, and for a number of years had been advised by his doctor to keep down his weight. Many of his movements seemed to entail an unnecessary expenditure of energy—he even wrote clumsily and seemed to spell out every letter slowly. When discussing anything or just telling a story he had an unusual and disconcerting way of peering into your face and on account of his height had to distort his body to do so. He was a tremendous enthusiast in everything he undertook. The labour, both mental and physical, which he put into every problem seemed to increase as time went on, and even on simple matters he would often exert himself needlessly. A nervous agitation in his actions could lead to tension with elder colleagues who preferred to go about their work quietly: to them he belaboured his points. He was critical of all papers submitted to him. The criticism usually took the form of a personal check on every equation, calculation or reference and involved him in what many would have considered unnecessary work. But there is no doubt that his energy and enthusiasm gave great encouragement to those in whose work he was interested and many will remember his help with gratitude. This was specially the case with the younger and subordinate members of his staff whom he encouraged to undertake research problems of their own as distinct from more routine duties.

I worked side by side with Greaves from 1924 till I went to South Africa in 1933. We had been on the friendliest terms for more than 9 years and I remember our parting well. He spoke as if we had worked together for a lifetime and seemed to feel the break more than I did. I was looking forward to new opportunities while he was staying behind and feeling the first gap in his working life. Those who only knew Greaves as an enthusiastic and determined astronomer may be surprised that he should speak feelingly on our separation. As it turned out there were a number of changes in the staff at Greenwich during his remaining 5 years there. Then at Edinburgh he had at first a staff nearing the retiring age, then the war. After that he recruited an entirely new staff and looked forward to another ten years of activity, but this was not to be.

We are greatly indebted to Greaves for the work he did on committees—local, national and international. At Edinburgh he served on the Council of the Royal Society, holding office as Secretary and Vice-President. For many years he was Chairman of the Robert Cormack Bequest Committee for promoting astronomical knowledge and research in Scotland. He acted as chairman of a small subcommittee of our National Committee responsible for the final draft of a resolution regarding the present needs of astronomy in this country. He took on the thankless job of chairman of the committee for nominating British members of Commissions of the I.A.U. and at the General Assembly of the I.A.U. was appointed chairman of the committee dealing with this problem. He had the impossible task of trying to please everyone. When he took up this appointment the committee spent long hours in sorting out the claims of representatives of many countries—hours which most of the members would have preferred spending otherwise. To him must be given some of the credit for the system which now allows much of the work to be done leisurely by post before the meetings of the General Assembly. Greaves did nothing by halves. I remember once telling him that I proposed passing on some information to an astronomer working in a rather isolated observatory. He agreed that I should do so and then added that it would be a mistake not to do so. He travelled many times (by air) from Edinburgh to London to attend meetings of committees and frequently intervened effectively at the meetings. He was a valued member of the Board of Visitors for the Royal Greenwich Observatory and for the Jodrell Bank Experimental Station on both of which he represented our Society. Earlier he had been one of those who had strongly advocated the importance of Radio-Astronomy and the need for the construction of a large Radio-Telescope in this country.

In 1926 he married Caroline Grace, daughter of H. D. Kitto of Whiteshill in Gloucestershire, who survives him with an only son. A younger sister of Mrs Greaves married the late Dr L. J. Comrie.

He was elected F.R.S. in 1943 and a Fellow of our Society in 1921.

I am indebted to Dr M. A. Ellison for assistance in preparing this notice.

J. JACKSON.

News of the death of WILLIAM BRADSHAW HOUSMAN of Seaton Observatory, Workington, Cumberland, was received with regret by many Fellows of this society. He had been in poor health during the last six years or so, having been bedridden for four months as early as 1950, but he had doggedly persevered with his observations whenever possible.

He was elected a Fellow of the Society on 1937 November 12, and died on 1955 January 17. One of his main interests in astronomy was the study of Aurorae, and for 23 years (1928–1951) he was Director of the Aurora and Zodiacal Section of the British Astronomical Association. Besides many Reports for the B.A.A. Journal, he produced three Memoirs on his Section's activities. His last Section Report appeared in December 1951, shortly after he had retired from his office as Director, owing to failing health. He continued to observe and report when fit, maintaining interest in his Section's work throughout.

William Housman will best be remembered by those who knew and collaborated with him in the '30s and early '40s, when he produced his best

work; but many others, who knew him, as I did, only in his declining years, will have felt the benefit of his kindly interest, the ever-present willingness to share his wide experience, and the drive of an enthusiasm which would turn his eyes towards the Northern Dawn or in quest of that more elusive and less spectacular phenomenon—the Zodiacal Light—when others, more robust, might find many valid reasons for ignoring both !

He was a painstaking and faithful observer, and his long and conscientious researches may serve as an encouragement to younger observers, and so further assist the cause of astronomy in general.

D. A. MACLEAN.

SIR FRANCIS McCLEAN, A.F.C., was best known to the outside world as a pioneer aviator, the patron of aviation and the founder of amateur and naval flying in Great Britain. His interest in astronomy was derived from his father, Dr Frank McClean F.R.S., and it took the form of active organization of eclipse expeditions and beneficent aid to the Norman Lockyer Observatory of which he was a joint founder. Born on 1876 February 1, he was educated at Charterhouse, Clifton and Cooper's Hill and served with the Public Works Department in India, 1898–1902. He flew in two Gordon-Bennett balloon races in 1907–8 and with Wilbur Wright in an aeroplane in 1908. He bought land at Eastchurch in the Isle of Sheppey, which he subsequently let to the Aero Club of Great Britain for 1*s* 0*d*. a year. He lent aircraft to naval officers so that they could learn to fly. In 1912 he flew up the Thames in an aircraft passing between the upper and lower parts of the Tower Bridge and, without touching water, under London Bridge. He joined the R.N.A.S. on 1914 August 6, and after service on the channel patrol became chief instructor at Eastchurch. Later he received a commission in the R.A.F.

He organized two eclipse expeditions, one to Flint Island for the eclipse of 1908 January 3, and one to Fort Davey in Tasmania for 1910 May 9 (an eclipse curiously omitted from the list given by Professor Mitchell in *Eclipses of the Sun*, p. 55). But he was dogged by bad weather on both occasions. The 21-inch siderostat which he bought for the 1910 eclipse he presented later to the Solar Physics Observatory at Cambridge. He also went with an eclipse expedition led by Sir Norman Lockyer to Vavau for the eclipse of 1911 April 28. His friendship with the Lockyers, father and son, led to his generous gifts to the Norman Lockyer Observatory to which body he gave a twin telescope complete with the (Frank McClean) dome and a sidereal clock. For some years he served on the Council of the Observatory under the chairmanship of his friend Sir Richard Gregory. Genial friendship was of the essence of his nature. He was High Sheriff for Oxfordshire in 1932 and he served for two periods as Chairman of the Royal Aero Club. A wide circle of friends will miss him greatly. He died on 1955 August 11, leaving a widow and two daughters.

He was elected a Fellow of the Society on 1902 November 14.

F. J. M. STRATTON.

On 1955 March 4 the REV. PAUL A. McNALLY, S.J., died very suddenly at Georgetown University where he had spent twenty-seven years of service.

As an astronomer he started his career in postgraduate work at the University of California in 1926, having previously obtained a Doctorate at Fordham University in New York. His plans to add another degree in Astronomy were interrupted in 1928 when he was called to Georgetown to assume the position of Director of the Observatory in the place of Rev. Edward C. Phillips, S.J.

At that time the Observatory was in great need of new equipment. The twelve-inch equatorial designed by Fr. John Hagen for his Atlas Stellarum Variabilium was the only useful instrument. The old transit instruments had remained idle for many years. Fr. McNally began observing occultations and a search for Herschel's fields with the old visual refractor, reserving a month or two each summer for additional research with the larger instruments at Lick Observatory. By 1932 he had added two three-inch Ross-type astrographic cameras for photographic work. One of these cameras was used in 1932 for the photograph of the total eclipse at Fryeburg in Maine, which won commendation at the Century of Progress Exhibit in Chicago and at the annual awards of the London Photographic Society. That expedition was organized and run by Fr. McNally with a budget of exactly $100. Perhaps the best reward for his enthusiasm was the peculiar favour granted by the weather, which was cloudy for most of the expeditions but left a hole in the clouds above the Georgetown site.

Subsequently, Fr. McNally took part in solar eclipse expeditions for the National Geographic Society in Siberia in 1936; on Canton Island in 1937 and at Patos in Brazil in 1940.

During the war when Georgetown, like all other universities, had to change its quiet academic pace to the speedy tempo of preparing student soldiers for war, Fr. McNally devoted his greatest efforts to liaison work between government and university administration. Scarcely had the end of hostilities come when superiors placed Fr. McNally in charge of the fund-raising campaign for the new university hospital. Fr. McNally's efforts in this work brought in funds a hundred thousand dollars over the original goal; and his appointment as Dean of the Medical School. Although not prepared for a career in medicine, his unusual drive and ability for administration won the highest praise from the American Medical Association for the medical school and the hospital came nearer than ever before to paying its running expenses. Such energy and self-sacrifice for the university he loved finally took its toll in health and by 1952 Fr. McNally suffered the first of a series of heart attacks which forced him into retirement for about two years.

In 1954 September he again undertook the assignment of organizing a graduate department of Physics and he died while engaged in this project with his usual enthusiasm.

He was elected a Fellow of the Society on 1929 March 8.

ROSS WALTER MARRIOTT was born in Paxton, Illinois on 1882 December 30, and died at Hahnemann Hospital in Philadelphia on 1955 October 19.

Ross Marriott entered the University of Indiana in 1902, where he obtained the Bachelor's degree in 1906. He came to Swarthmore with the late Dr John A. Miller, when the latter came to Swarthmore College in 1906 as Professor of Mathematics and Astronomy. He received the Master's degree

at the University of Pennsylvania in 1911. He taught Mathematics at Swarthmore College for forty-six years, as an Instructor (1907–1910), Assistant Professor (1910–1922), Associate Professor (1922–1927), and Professor of Mathematics and Astronomy (1927–1952). Marriott took an active part in making the adjustment of and early observations with the Sproul 24-inch refractor after it was installed in 1911.

From 1923–1932 Marriott participated with Miller in the Swarthmore Eclipse expeditions, and due to his zeal and care Swarthmore College possesses a collection of fine coronal photographs. In the Director's office of the Sproul Observatory hangs an oil painting by the late Owen D. Stephens (well-known artist of astronomical subjects) of Miller and Marriott studying a solar eclipse photograph.

Marriott was a perfectionist, and was more than critical of the results of his own observational efforts. He did not publish the measurements and discussions of some of his best plates, because he was not satisfied with the results.

The definition of Marriott's eclipse photographs is excellent; solar astronomers recognize the value of his large-scale photographs of the solar corona, which he generously shared, together with his unique knowledge about them. Outstanding are his large-scale photographs of the inner and outer corona at the time of the eclipse of 1930 October 21 at Niuafoou, Tonga ("Tin Can Island"), which are of exquisite quality and have been analysed by several astronomers, particularly for the "jets" or small spicules.

The fruits of his long period of service in the teaching profession, and his valuable collection of eclipse photographs, remain as a monument to Ross W. Marriott of Swarthmore College.

He was elected a Fellow of the Society on 1923 January 12.

PETER VAN DE KAMP.

PETER YORKE MILLNS was born on 1933 May 1 at Rotherham, Yorkshire, as the first son of Mr John Cyril Millns and his wife Mabel, née Hope. He was educated at the Rotherham Grammar School and, since 1951, at the University of Manchester, graduating in physics with first-class honours in June 1954. His inclinations prompted him to choose astronomy as the subject of his post-graduate research, and a quest for clear skies led him repeatedly to the High Alpine observatory at Sphinx, Jungfraujoch, where he prematurely lost his life as the result of an accident on 1955 December 19, aged 22 years.

These few terse facts do but scant justice to the personality and achievements of a brilliant budding scientist and lovable colleague, whom his University and his country had the misfortune to lose so early in his life. When Peter Millns, after receiving his B.Sc. degree, was ready to enter research, his imagination was captured by the recent nebular-photography work of the Russian astronomers Fessenkov and Rojkovsky at Alma Ata, and Shajn and Hase at Crimean Astrophysical Observatory, who, using Maksutov-type astrographs of focal ratio f/1·4, did so much in post-war years to extend our knowledge of the distribution of excited hydrogen in interstellar space.

Fortunately for Peter, the H. H. Wills Physical Laboratories of Bristol University have, since 1950, been developing (under the auspices of the Paul Instrument Fund of the Royal Society) ultra-fast wide angle meniscus Schmidts

for meteor photography at Jodrell Bank; and a small-scale plate glass model of such a camera, of 6-inch free aperture, f/0·67 focal ratio, and 46° usable field happened to be available at the time. Thanks to the cooperation of Professor M. H. L. Pryce, Peter was enabled to obtain this camera on loan for his work; and through the kindness of Dr P. von Tavel in Berne and Dr D. Chalonge of the Institut d'Astrophysique in Paris he was eventually able to attach it to the equatorial table of the French telescope at Sphinx, Jungfraujoch, in superb observing conditions at an altitude of 3 576 m.

In contrast to the Maksutov cameras of the Russian investigators, the Bristol plate-glass camera had inferior resolving power, but it was about four times as fast, and its large field made it an effective instrument of search for nebulosities fainter than those recorded by any previous investigators. In order to attain this aim, the real problem is to increase the nebula-night sky contrast by suitable filters transmitting the desired emission, but cutting off as much as possible of unwanted air-glow.

When Peter was ready to embark on research, Wurm's communication before the 6th Liége Astrophysical Conference in July 1954 attracted his attention to the possibility of using organic dye filters for this purpose. Unlike interference filters, dye filters can be produced in any practical size, and their transmissivity remains unimpaired by the angle of incidence. Can they be made also sufficiently transparent and selective at the desired wave-lengths? With the expert advice of Dr E. Clar of the Department of Organic Chemistry of Glasgow University, and later of Dr A. Burawoy of the Manchester College of Technology, Peter tested and located within less than a year, not one, but several organic dyes exhibiting suitable sharp absorption cut-off immediately to the blue of Hα, or of HeI 5876*; while the other branch of the passband was to be supplied by rapidly diminishing sensitivity of Eastman 103a-E or 103a-T emulsions. These plate-and-filter combinations were characterized by pass-bands rather less than 100 A wide, and transmitting approximately 50 per cent of light of Hα or of HeI 5876. The first results of this investigation were reported by Millns at the Manchester Symposium on Astronomical Optics in April 1955, and will appear posthumously in Peter's first—and last—paper to be published in the Proceedings of the Symposium—a volume now dedicated to the memory of its youngest participant. The camera and its associated dye filters were first tested at Jungfraujoch in May 1955, and the combination of filters and of the observing site proved so successful that, whereas in Manchester an exposure of only 2 minutes appreciably fogged the plate in the focus of an f/0·7 Schmidt in integrated light, at Jungfraujoch it eventually became possible to expose with the same camera through a red dye filter as long as 4 hours without any greater degree of fog. This limit was, however, not attained till December 1955, and much work had to be done in the meantime. In August and September Peter attended the 9th General Assembly of the International Astronomical Union in Dublin, and in October and November worked out, in cooperation with Dr W. Berg of Kodak Research Laboratories at Harrow, new methods for coating curved plates of the Bristol Schmidts with red emulsions without loss of sensitivity (which did affect his earlier experiments in May).

Equipped with these new plates, he set out for Jungfraujoch in the first

* Such as di-ortho-phenylene tetracene or Michler's hydrol for Hα, and tetra-chloro-tetracene or astrophloxine for HeI 5876.

week of December 1955 for an expedition from which he was not to return. The weather was favourable, and all went well until the fateful Monday, December 19. The night before was superbly clear, and Peter worked at Sphinx till dawn. Before noontime, he and his colleague, Dr Warwick A. Cooper of the Geneva Cosmic Ray team, went out to take a few snapshots of the Sphinx cliff from the neighbourhood of the Mathildaspitze, a few hundred yards from the Jungfraubahn Hotel. The weather was sunny and calm, but after a while Cooper turned back to attend to culinary duties of their bachelor establishment. He was the last person to see Peter alive. When Peter failed to appear for lunch, Cooper, accompanied by Mr H. Wiederkehr, Superintendent of the Research Station, went to look for him outside. They had no difficulty in picking up his footsteps in snow—leading, alas, to an ominous hole in a thin snow bridge covering a deep crevasse. Calls in its depth by anxious friends evoked no response. A rescue party of experienced guides, summoned hurriedly from Kleine Scheidegg, descended some 170 feet of its depth, and found at the bottom a pool of slush and water several yards deep, with which they were unprepared to cope. It was not till the next noon that a better equipped party from Grindelwald, led by Bergführer Ch. Bohren, succeeded at last in recovering Peter's lifeless body from its depth. In looking for a position from which to take a snapshot of the observatory—he had only one more film left in his camera—Peter inadvertently stepped over a snow bridge covering a deep crevasse, which gave way under his weight and sent him 170 feet into the depths of the glacier. The fall itself apparently caused him no injury, but in falling down he lost consciousness and the cause of his death was drowning—in an underground pool of water of the Guggi glacier, some 3 400 metres above sea-level in the middle of winter and only a few hundred yards from a place where thousands of tourists pass every year. A more improbable and more tragic chain of events could scarcely be imagined.

Peter's colleagues at the Jungfraujoch as well as Professor A. von Muralt and Dr P. von Tavel at the Berne Headquarters of the Research Station, did their best to attempt to rescue him while there was hope, and to arrange later for his last journey home. He returned in the coffin to his family in Rotherham on Christmas Eve of 1955, unable to tell what happened in the last seconds of his life, and was laid to his rest in the graveyard of the Parish Church of Wickersley in Yorkshire on December 27.

Peter Millns is being survived by his parents, his fiancée, two sisters, and a younger brother, John Christopher, who shares Peter's interests in our science and has already taken his place on the membership roster of our Society. Peter was elected Fellow of the Society on 1955 May 13.

ZDENĚK KOPAL.

THOMAS ROYDS died after a short illness at Southport on 1955 May 1. He was born at Oldham on 1884 April 11. As a student at the University of Manchester he began his researches in spectroscopy under Sir Arthur Schuster, though his first paper, *On the Constitution of the Electric Spark*, was not published until after Schuster had retired and been succeeded by Sir Ernest Rutherford. With Rutherford, Royds published papers on the Spectrum of Radium Emanation, on the nature of α-particles and their identification with helium atoms. With an 1851 exhibition he went to Germany working with Paschen in Tübingen and Rubens in Berlin, and publishing work on the measures

of Zeeman resolutions of lines of *Cd*, *Zn*, *Mg* and *Hg*, which had been discussed by Paschen for series relationships. He continued work with rapidly moving films on the motions of metallic vapours in the condensed spark and in 1912 he was granted the degree of D.Sc. by Manchester University.

Meanwhile he had been appointed, in 1911, Assistant Director to Mr J. Evershed at Kodaikanal Observatory in Southern India. His first papers published in the Bulletins of the Observatory dealt with periodicities in prominences and their distribution on the solar disk. Among other points examined was a possible planetary effect; he found no evidence for any real effect. He then returned to spectroscopic work examining displacements of lines in the solar spectrum from the wave-lengths in the arc. He traced displacements to the violet and to the red to differences of vapour density and noted that the longer the arc, the more nearly the arc lines approached those in the reversing layer of the Sun. With Evershed he examined the relation between the displacements and intensities of the lines. They found that limb-centre shifts decreased with growing intensity, centre-arc shifts similarly increased. The result was that limb-arc shifts were approximately the same for all intensities and represented a general movement away from the Earth. Royds further examined shifts between the pole and centre of the arc and found that these, along with displacements of unsymmetrical lines, could be best explained in terms of vapour density; though he also found that pressure shift had to be taken into account in a discussion of the different behaviour of lines belonging to the same spectral series. He also found that nickel and titanium lines showed the same differences between Sun and arc as the iron lines and examined the effect of introducing various substances into the arc. His last and in some ways his most important contribution to the study of displacements of lines at the limb was his measurement of lines at the extreme limb of the Sun, observed at the total solar eclipse of 1936 June 19. He was a member of the Joint Permanent Eclipse Committee's expedition to Kamishari in the island of Hokkaido and the only one to get any results, as the clouds beat the Moon in the race to cover the Sun's disk in what can properly be described as a photo-finish. Royds found that differences of shift for lines of different intensity were maintained right up to totality and could not be ascribed to scattered light from the centre of the disk. Relativity theory was not adequate to give a complete explanation of the displacements observed.

Royds succeeded Evershed as Director of Kodaikanal Observatory in 1923. In the latter part of his time there, his interest and activity shifted from spectroscopic work to the study of spectroheliograms. Dark markings on the Sun came especially under observation and Royds studied their heights, their distribution and the changes of inclination to the solar meridian with latitude and with time. These changes he found to be explained by the equatorial acceleration in solar rotation. In a study of quiescent and eruptive prominences he showed himself opposed to the theory of radiation pressure as the cause of upward movements. He published an account of one prominence rising to a height of 567 000 km with a terminal velocity of 229 km/sec and another observational paper in 1926 on unusual bright filaments on the Sun, resembling in appearance later outbursts now connected with radio disturbances.

He retired from Kodaikanal in 1939, but in 1942 at the instance of the British Council accepted an invitation to go out to Istanbul as Professor of

Astronomy, where he lectured in Turkish. He finally retired in 1947 to live in Southport until his death. He was survived by his widow with two daughters and a son.

He was elected a Fellow of the Society on 1913 January 10.

F. J. M. STRATTON.

JOHN LESLIE RUDD collaped suddenly at Holmbury St. Mary on 1955 March 11, and failed to regain consciousness. He was waiting for a bus with his wife and two children while on his way to a meeting of the Royal Astronomical Society.

Rudd was born at Greenwich on 1914 February 21 and educated at the Boreman Foundation (Royal Hospital School). He was appointed as a computer at the Royal Observatory in 1930 and became a member of the established staff in 1936. After a period of service in the Tidal Branch of the Admiralty, he rejoined the Observatory as a member of the Time Department in 1940 when a war-time station was being set up at Abinger. He was married in 1941 to Betty Fry, the daughter of two other employees of the Observatory. He was notified in 1954 that he would take up new duties at Herstmonceux the following spring, and he and his family were eagerly making preparations for the removal.

During the period that Rudd was in the Time Department, he was primarily concerned with the essential day-to-day operation of the Time Service and in recent years he had been in charge of all the work at Abinger concerned with the reception and measurement of radio time signals, the current assessment of clock performance, and the exchange of data with co-operating establishments. He was an experienced observer and took regular duties on the Bamberg transit instrument.

Much of the work of a national observatory provides little scope for dramatic individual achievement: it demands efficient, conscientious, smooth-running team work. Rudd was ideally suited to work of this nature and his colleagues will long remember his co-operative, friendly and straightforward manner. He took a leading part in staff social activities, and at many local functions. His sudden death at the early age of 41 was a profound shock to all relatives and friends. He leaves a widow and two daughters, Susan and Lindsay, aged 8 and 5.

He was elected a Fellow of the Society on 1944 February 11.

ROBERT MELDRUM STEWART was born on 1878 December 15 in Gladstone, Manitoba. His death on 1954 September 2 brought to a close a life of devotion to his family and to his chosen profession of astronomy. Actively associated with the Dominion Observatory, Ottawa, for 44 years, he was its Director for half that period and as Dominion Astronomer was Canada's counterpart of the Astronomer Royal.

Born of Scottish-Canadian parents, he was the son of Rev. James J. and Mrs Stewart. As a Presbyterian clergyman, Rev. Stewart was engaged in missionary work in Western Canada at the time of his son's birth. For some years the family resided in small communities where educational facilities were not always the best, and as a result Rev. Stewart tutored his son until he was prepared to enter High School.

Although thoroughly grounded in Greek, Hebrew, Latin and in English literature, his love for the logic of mathematics finally turned his thoughts toward a scientific career. He entered the University of Toronto in 1898 after winning practically all the scholarships offered by his school. Following a course in Mathematics and Physics, he graduated with high honours and was the Gold Medallist of his year. A master's degree in 1903 closed Meldrum Stewart's university education, but he never ceased to be a keen student, not only of the developments and progress being made in astronomical and allied scientific fields, but also of the classics. His was a well balanced education, giving him a love for and appreciation of the finer things of life.

At the turn of the century Canada was still a young country and her Astronomical Branch—later to become the Dominion Observatory—was engaged in the establishment of a network of latitude and longitude stations across the country; this work had been undertaken in connection with the construction of a transcontinental railway. Meldrum Stewart joined the Branch in 1902 and immediately showed marked aptitude for precision and detail. He realized that an efficient time service was necessary for accurate longitude determinations and that with the inevitable growth of the country precise time would become increasingly important. This phase of work formed the centre but by no means the boundary of his interest and research throughout his long association with astronomy.

When the astronomical staff moved from temporary quarters to the present Dominion Observatory building in 1905, Mr Stewart was appointed Superintendent of the Time Service, and retained that position until he was named Director of the Observatory in 1924. Upon his shoulders fell the task of establishing this basic astronomical work and to him must go much of the credit for developing Canada's Time Service to the high degree of efficiency which it has attained.

During the first few years much time was required for organization and for making plans upon which the future of the Observatory would be founded. The installation of a 6-inch Meridian Circle telescope in 1907 was one of the first major problems assigned to Mr Stewart. He proved his versatility in dealing with and surmounting the many instrumental difficulties which were encountered. For many years he did a considerable amount of the observing, as well as supervising an extensive programme undertaken to determine fundamental star positions. The three published catalogues containing accurate positions of many thousands of stars now form a lasting tribute to R. Meldrum Stewart's meticulous endeavours.

As a pioneer in Canadian astronomy it was Mr Stewart who devised the system of obtaining longitude by the use of wireless time signals, when that programme was extended to stations remote from telegraphic communications. The first station thus occupied was in the province of Quebec in 1914. Longitude work in connection with surveying was discontinued by the Observatory in 1923, but three years later and again in 1933, Canada, under Mr Stewart's direction, participated in world longitude programmes.

As had been anticipated by Mr Stewart the need for the distribution of time to many parts of the country was increasing with the continued growth of Canada, and it was evident that existing facilities would require vast improvement and extension. While the Observatory was declared the source of official

time for Canada only in 1941, it had served unofficially in that capacity for many years prior to that date. Time impulses had been sent from the Observatory to the local telegraph offices as early as 1905, but the first wireless transmission over local broadcasting stations did not come until 1923. Four years later radio broadcasting was to emanate directly from the Observatory, using short wave frequencies. Until 1935 the basic instrument with which time observations were taken was the Meridian Circle telescope. It was then replaced, for time observations only, by a 3-inch broken-type Cooke transit telescope. More recently the latter has been superseded by a Photographic Zenith telescope.

During the mid-thirties an idea was evolving in the fertile mind of Mr Stewart and his conception was later realized with the construction of his Time Signal Machine. In 1938 this unique machine went into operation, marking another advance in time distribution methods. A pendulum provided the control for the instrument, which at that time was cleverly held to true time by a Shortt pendulum clock. When a crystal clock was installed in 1942, it became the controlling unit rather than the Shortt clock. Services supplied by this machine included (1) the noon broadcast over the Canadian Broadcasting Corporation network; (2) continuous short wave time signals on three frequencies from the Observatory's transmitting station CHU.; (3) other radio transmission such as to the two major telegraph companies; (4) additional services including the control of some 800 dials in various Government buildings.

Mr Stewart's scientific interests were broad, and ranged from radio-activity, meridian work, time service, longitude by wireless, to the theory of errors. As Dominion Astronomer he was the guiding spirit not only of the Dominion Observatory with its five major divisions of research (Positional Astronomy and Time Service, Stellar Physics, Terrestrial Magnetism, Gravity and Seismology) but also of the Dominion Astrophysical Observatory at Victoria, British Columbia. His administrative duties increased with the passing of years, but in spite of this his constructive interest in all research problems of both observatories never waned. As a lecturer and writer he was well known and many of his scientific papers have appeared in various astronomical publications.

Mr Stewart took an active part in a number of scientific organizations. He was a Fellow of the Royal Astronomical Society of Canada and of the Royal Society of Canada, and held various offices in the former society. Other organizations in which he held membership or office were, National Committee for Canada of the International Astronomical Union; American Association for the Advancement of Science; American Astronomical Society; Astronomische Gesellschaft and La Société Astronomique de France.

In his younger days he was active in a number of sports, boating being his chief outdoor recreation in later years. His indoor interests included carpentry and chess, and like many other scientists Mr Stewart had a fondness for music. Following in the tradition of his father, he and his family were members of St. Andrews Presbyterian Church, Ottawa.

Because of his retiring nature, it was not given to many to know Mr Stewart intimately, but he will be remembered by his co-workers for his keen analytical mind, and high standards of integrity and duty. Those who, like the writer, were privileged to be associated with him in his scientific work knew him as a brillaint mathematician—considered outstanding in his day—and learned to

appreciate his many sterling qualities.

Astronomy has suffered a severe blow; his colleagues have lost a loyal and sincere friend, and society a truly distinguished gentleman. Without scientists like Robert Meldrum Stewart, Canadian astronomical and geophysical research would not have attained the position it now holds in international circles.

Mr Stewart is survived by his widow, the former May Dickson, whom he married in 1904, two daughters, Mrs W. K. Ross of Montreal and Mrs Wilfrid Saunders of Toronto and six grandchildren. Three children predeceased him, two daughters, Dorothy and Molly who passed away in recent years, and a son who died in infancy.

He was elected a Fellow of the Society on 1915 April 9.

MIRIAM S. BURLAND.

PROCEEDINGS OF OBSERVATORIES

Royal Greenwich Observatory

(Director, Dr R. v.d. R. Woolley, O.B.E., F.R.S., Astronomer Royal)

Nautical Almanac Office.—The 1956 editions of the annual publications of the Office and the four-monthly parts of the *Air Almanac* for 1955 May to 1956 August have been published during the year; no changes in content have been made in these publications. The various stages of publication reached for the 1957 editions make it probable that the publication dates will be appreciably in advance of those in recent years. All other work of the Office, including the prediction and reduction of occultations, has been continued. Predictions of occultations of radio sources are now undertaken regularly; the predictions are being sent directly to all institutions which have equipment for such observations.

As mentioned in last year's report, the copy for the *Abridged Nautical Almanac* is being produced on the card-controlled typewriter as from 1958. It has now been agreed that from 1958 the *American Nautical Almanac* and the *Abridged Nautical Almanac* shall be, apart from a few introductory pages, identical publications; they will be printed by photolithography from identical material, but published separately in the United States of America and in the United Kingdom. The work of preparation, compilation and proof-reading will be shared between the Nautical Almanac Offices of the two countries. Reproducible material will be made available to the official almanac-producing agency of any country that wishes to make use of it; several have already indicated their desire to do so.

This decision means that, in the future, the ephemerides for the use of astronomers, of surface navigators and of air navigators will all be completely unified with the corresponding U.S. publications, and that all English-speaking astronomers and navigators will use identical data. Western Germany will also use the unified astronomical ephemeris instead of the *Astronomisch-Geodätisches Jahrbuch*, which will cease publication after 1957.

The introduction of punched-card and other computing machines into many ephemeris offices has made it more economical for these offices to perform larger amounts of one particular calculation during a specified period. So that the best use can be made of present-day facilities, some changes have been made in the allocation of calculations among the various ephemeris offices; these changes are to be introduced from 1960. Arising from this new allocation, agreement has been reached that as from 1960 the Astronomisches Rechen-Institut at Heidelberg will take over the compilation and publication of the international volume of *Apparent Places of Fundamental Stars.*

A new and much extended edition of the booklet *Interpolation and Allied Tables* has been prepared and is in the course of printing; publication will take place about June 1956. A companion booklet on *Subtabulation* is in course of preparation.

The calculations for *Planetary Co-ordinates for the Years* 1960–1980 have been completed. Copy for the tables is being prepared on the card-controlled

typewriter, and it is expected that publication will take place before the end of 1956.

Calculations have been essentially completed for the agreed share (southern latitudes) of the new edition, for equinox 1960.0, of Vol. 1 of A.P. 3270 (H.O. 249 in U.S.A.), *Sight Reduction Tables for Air Navigation.*

Meridian Department.—Installation of the Cooke R.T.C. in its new housing is nearing completion. The circle-reading cameras are in position but not yet adjusted; the apparatus for controlling the exposures, stepping on the films and counting the exposures has been made in the Observatory workshop and is installed on the telescope piers. The azimuth-mark lenses were received from the makers, and tested at Greenwich. Cells for them were made in the workshop.

P.Z.T.—Installation is complete. Since September over 50 plates have been obtained containing approximately 9 stars per plate. Reduction methods have been designed together with various auxiliary reduction tables. Some of the minor faults in the instrument have been corrected, others reported to the makers for correction.

The scale errors of the Zeiss measuring machine have been determined.

Time Department.—Astronomical observations for time determination have been made throughout the year, using Small Transit C in the Courtyard Dome at Greenwich, and the Bamberg Broken Transit at Abinger. A short-circuit in the registration circuit of the latter instrument was caused by excessive condensation on November 4, and the instrument was removed to the workshop for a few days for re-wiring and overhaul. During the year 281 observations were obtained on 193 nights at Greenwich, and 237 observations on 138 nights at Abinger, making a total of 518 observations for the two stations.

The normal regular comparisons were made with foreign radio time signals (including those associated with standard frequency transmissions) and with the MSF 60 kc/s and Droitwich 200 kc/s carrier frequencies. The time service has been operated from Abinger throughout the year, with Greenwich providing a reserve service for certain signals. The routine publication of the Monthly Frequency Estimate, the Time Service Circular and the Time Service Bulletin has continued. Further progress has been made in reducing the arrears of copy for the volume of Greenwich Observations.

Astrometry and Astrophysics Department.—During the year the 13-inch Astrographic secured 1 exposure on Ceres, 28 on Pallas, 19 on Juno, and 13 on Vesta; 25 plates were taken on other minor planets and 6 on various comets.

Exposures were continued on three star-fields at widely different declinations in order to investigate the systematic errors dependent on hour-angle; 61 plates were secured during the year. Small systematic effects are now confirmed in declination as well as in right ascension, but the sign as well as the magnitude of the effects varies with the declination of the test field in a way that makes a physical explanation difficult to picture.

In co-operation with the Cambridge Observatories, some plates taken with the new 17/24 in. Schmidt camera at Cambridge have been examined to assess the suitability of such an instrument for astrometry. The results are promising. The complicated reduction formulae found necessary in astrometric work with Schmidt telescopes elsewhere are believed to result from the use of the ordinary standard-co-ordinates method of reduction. A more appropriate method has

been developed that enables a linear reduction to be used, at any rate for work that does not demand the highest precision.

The 36-inch mirror of the Yapp telescope was under test by Messrs. Cox, Hargreaves and Thomson during the early weeks of the year. The quasi-permanent patchy errors of figure noticed in use, and the suspected presence of astigmatism, were not confirmed in laboratory tests of the mirror supported on its edge, but there is a fairly wide turned edge, and large zonal errors exist round the central hole. These are almost covered by the 11-inch secondary in Cassegrain work, but not by the 7-inch paraboloid.

The mirror was remounted on March 29, and between that date and November 21 (when dismantling commenced prior to removal to Herstmonceux) 118 spectra of 89 stars were secured. Complete mechanical overhaul and re-wiring, where necessary, is being carried out at Greenwich before re-erection at Herstmonceux.

Solar Department.—The Sun was photographed in white light with the 4-inch photoheliograph at Herstmonceux on 301 days during 1955. Up to November 30 one day is missing from the combined Greenwich–Cape–Kodaikanal series. Cape negatives in duplicate have been received up to 1955 September 30.

Measurement of the combined series of photographs has been made for the period from 1954 August 4 to 1955 July 11. Copy for press of *Greenwich Photoheliographic Results* has been completed up to the end of 1954, the volumes for 1946 and 1947 having been published during the year. Summary tables of mean areas and mean latitudes of sunspots during 1951 and 1952 have been published in *Monthly Notices* and those for 1953 and 1954 are in course of publication.

A special publication, entitled *Greenwich Sunspot and Geomagnetic-Storm Data*, 1874–1954, has been completed and published during the year, and over 400 copies have been distributed. This volume contains a number of tables giving homogeneous Greenwich data over the eighty-year period, including monthly mean daily areas of sunspots and faculae, catalogues of the largest sunspots and of geomagnetic storms, and a latitude-time "butterfly" diagram of sunspots covering seven complete cycles of solar activity.

With the Levallois–Lyot birefringent filter on the 6-inch Newbegin refracting telescope, regular observations in Hα light were commenced on 1955 June 13. Subsequent to that date photographs of the Sun's disk were made on 116 days and for a similar number of days a record of the prominences at the Sun's limb was obtained. Solar prints to a standard size of 20 cm to the Sun's diameter have been made for each day represented. Detail in the bright plages around sunspots, large and small dark filaments, and the general mottling of the surface are all clearly visible in the Hα disk photographs. Solar flares have been recorded on 12 occasions, though good sequences of photographs were obtained for only three of these flares.

With the spectrohelioscopes, the Sun was observed in Hα light on 160 days during 1955. 16 solar flares were observed, including two of importance 2.

The continuous record of atmospherics at a frequency of 27 kc/s showed 29 typical enhancements (S.E.A.'s) due to the u. v. effects of solar flares during Greenwich daylight hours.

Work on the coelostat and secondary mirror mounting for the underground

solar spectrograph has continued in the workshop. The 10½-inch objective was received from Messrs Cox, Hargreaves and Thomson early in the year.

The provision of current information of solar activity by the Department has been reviewed during the year and an attempt is being made to serve during the forthcoming solar cycle all individuals and institutions who might benefit from such information. The special publication on Greenwich Sunspot Data was the last major contribution made by Mr H. W. Newton, who retired on 1955 May 31 after 42 years' continuous service with the Observatory, including 37 in effective charge of the Solar Department—incidentally the only part of the Observatory which remained operative at Greenwich throughout the second war.

Royal Observatory, Edinburgh

(*Director, Professor W. M. H. Greaves, F.R.S., Astronomer Royal for Scotland*)

Stellar Spectrophotometry.—Publications of the Royal Observatory, Edinburgh, Vol. **1,** No. 6, covering the results for seven stars of Spectral Type B1, appeared during the year. Seven further B1 stars have now been reduced and a paper analysing the results for all these fourteen B1 stars is in the manuscript stage. This publication will appear in 1956 and will include mean plots representative of the spectra of a B1 super-giant and of a B1 dwarf in the regions 4125 A–4980 A, 5630 A–5970 A and 6120 A–6770 A.

The reduction of nine stars of types O6–B0 is completed. In addition the data for the seven O-type stars given in *Publications of the Royal Observatory, Edinburgh*, Vol. **1,** No. 2, have been extended and revised. All sixteen of these stars will be analysed together. Dr R. Wilson has detected emission lines of C III and N III in some of these stars, the intensities of the C III line being correlated with the Yerkes luminosities of the stars in question (see *The Observatory*, **75,** 222, 1955).

The measurement of the spectra of stars of type B2 (18 in all) is completed and a start has been made on the B3 stars. The reduction of the B2 data is well advanced.

Observational work with the 36-inch telescope and Cassegrain spectrograph has been carried on throughout the year to replace programme plates which were found not to be of suitably high standard. In all 94 spectra were obtained on 46 nights. It has been proved that the exposure meter mentioned in last year's report materially assists the observer as well as ensuring plates of a uniform standard of density.

Solar work.—The Sun was observed on 127 days, and Hα observations were made with the spectrohelioscope on 122 days. Nine flares were observed during the year: 2 of Class 2, 3 of Class 1 and 4 of Class 1⁻.

The recorder which shows the integrated level of radio atmospherics on a frequency of 24 kc/s was kept in continuous operation, and 33 sudden enhancements of atmospherics (S.E.A.'s) were recorded. The increasing number of these sudden ionospheric disturbances due to solar flares is indicative of the rapid rise in solar-activity which has taken place during the year. The yearly numbers of S.E.A.'s. recorded at Edinburgh since 1950 have been as follows:

Year	1950	1951	1952	1953	1954	1955
S.E.A's	82	81	22	7	0	33

As part of the I.G.Y. programme for the study of sudden ionospheric disturbances, a cosmic noise recorder was installed which operates on frequencies near 18 Mc/s. This consists of a dipole aerial with reflecting mat, the aerial and connecting cables being suitably matched to the receiver. Experiments are proceeding to reduce the effects of interference which are at times troublesome during daylight hours. Five sudden absorptions of cosmic noise (S.C.A's) were recorded with this apparatus during the last six months of the year : these five coincided with the occurrence of S.E.A's and four were coincident with short-wave fade-outs, as reported by Cable and Wireless.

A contract for the supply of a Lyot-type Hα Heliograph has been placed by the Admiralty, acting on behalf of the British National Committee for the International Geophysical Year. This instrument will be constructed by the firm of S.E.C.A.S.I. at Bordeaux and will be similar in design to that which has been successfully developed at Meudon. With the co-operation of H. M. Astronomer (Dr R. H. Stoy), it is planned to operate the instrument at the Royal Observatory, Cape of Good Hope, where daily sunshine hours average 68 per cent of possible. The heliograph will be fully automatic and will take films of the Hα chromosphere at 30-second intervals for purposes of flare patrol and flare photometry during the I.G.Y. The analysis of the films will be undertaken at Edinburgh.

Further plates of the spectra of limb prominences have been taken during the year with the combined spectrohelioscope and spectrograph. It is hoped to publish the results for the line profiles of the Balmer series and for the H and K lines during 1956.

Stellar photometry.—Dr V. C. Reddish has begun a programme of 3-colour photometry with the Schmidt telescope. The purpose of the programme is to find further clusters intermediate in type between Populations I and II. A theoretical paper on the period-luminosity relation in Population II has been published (*M.N.*, **115,** 480, 1955) and an investigation is being made into star formation and heavy element production in the early history of galaxies.

Time-service.—The mean-time clocks, Riefler 258 and Leroy 1230, have maintained satisfactory rates. The signals from one or other of these clocks have been used, as in former years, to regulate the local time-service to the city of Edinburgh. The same signals control the firing of the time-gun at 1 p.m. daily from Edinburgh Castle and the fall of the time-ball on the Nelson Monument at the Calton Hill. The centenary of the operation of the time-ball was marked by a brief ceremony on 1955 January 1 which was broadcast from the Castle and the Calton Hill. The President of the Edinburgh Chamber of Commerce (Mr James Allen), Dr M. A. Ellison representing the Astronomer Royal for Scotland, and Mr Robert Mitchell representing the firm of Messrs James Ritchie and Sons (who have maintained the gun circuits since 1861 and have serviced the time-ball since 1895) took part in the commemoration. The " one o'clock gun " was first fired successfully from the Castle battlements on 1861 June 7 (it had failed to fire at the inaugural ceremony two days previously).

The master movement of Shortt 4 (siderial time) was cleaned and repaired during the year at the Chronometer Repair Department, Royal Greenwich Observatory.

Seismology.—Our thanks are due, as in former years, to Mr E. Tillotson for undertaking the reduction of the Milne–Shaw seismograms and for answering correspondence relating to them.

Colloquia.—During the year Colloquia have been held in the Observatory dealing with the following subjects:—Molecular Astrophysics (Dr R. Wilson), Intergalactic Space and the Recession of the Galaxies (Dr J. Cisar), Recent Work in Stellar Kinematics (Professor W. M. Smart), Problems of Galactic Evolution (Dr V. C. Reddish), Rainfall and Meteoric Dust (Dr R. A. Lyttleton), A recent tour of Russian Observatories (Dr M. A. Ellison), The Atmospheric Spectrum in the Infra-red (Dr D. M. Gates).

Visitors.—In addition to those who have spoken at Colloquia, visiting scientists have included Dr and Mme L. d'Azambuja, Dr G. Contopoulos, Dr D. Cotsakis, Dr A. K. Das, Dr F. K. Edmondson, Mr Charles A. Federer Jr., Dr V. Guth, Dr F. Haddock, Professor N. Kemmer, Dr A. McKellar, Dr M. Plavec, Dr B. Sternberk, Dr Z. Svestka, Dr A. D. Thackeray, Dr J. P. Wild, Miss F. W. Wright and Dr K. O. Wright.

Personnel.—On 1955 December 24 astronomy generally, and the Observatory in particular, suffered a severe blow by the sudden death of the Director (Professor W. M. H. Greaves, F.R.S.). Professor Greaves had been Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh since 1938. An appreciation of his life and work is given on p. 145.

Mr J. H. Reid joined the staff in September as Assistant Experimental Officer. Dr J. E. Gibbs, who had been working at the Observatory as a Cormack Fellow of the Royal Society of Edinburgh, resigned his Fellowship in December in order to take up a post at the National Physical Laboratory.

Royal Observatory, Cape of Good Hope

(*Director, Dr R. H. Stoy, H.M. Astronomer*)

Gill Reversible Transit Circle.—The observations for the *Second Cape Catalogue for* 1950·0, which were begun in 1951, were continued. The working list now contains approximately 7000 stars and includes the usual Cape clock and azimuth stars, all FK3 stars south of $-20°$, all GC stars brighter than $8^{m}{\cdot}5$ between $-30°$ and $-52°$ and between $-80°$ and the South Pole, a selection of stars south of $-80°$ to serve as standards for the reduction of the photographic zone observations and a number of extra stars added at the beginning of 1955. These extra stars include 396 stars between $-29°\,30'$ and $-40°$ which, together with the stars already in the working list, will provide a sufficient number of evenly distributed stars for the reduction of photographic plates to be taken in Australia with the Yale Observatory Camera. They also include 65 stars south of $-30°$ taken from the FKSZ list of 931 faint fundamental stars. The other 221 FKSZ stars south of $-30°$ were already included in the working list or have been observed with the Gill Reversible Transit Circle within the last ten years.

Several of the stars have now received their full quota of eight observations, four in each position of the instrument. The stars south of $-80°$ received preferential treatment and the observations for them were completed in 1954.

During 1955, a total of 7521 transits was observed. This includes 288 observations of stars during the day time and the following observations of bodies in the solar system :—

Sun	119	Jupiter	12	Vesta	7
Moon	34	Saturn	20	Pallas	1
Mercury	54	Uranus	18	Ceres	16
Venus	79	Neptune	19		

Cape Photographic Catalogue for 1950·0.—Work on this project has proceeded steadily. The volumes covering the zones $-35°$ to $-40°$ and $-52°$ to $-56°$ were published during 1955. The volume covering the $-56°$ to $-60°$ and $-60°$ to $-64°$ zones is in course of preparation. The reductions for the $-64°$ to $-68°$ zone have been completed and the measurement of the $-68°$ to $-72°$ zone commenced.

Parallax Programme.—The observations for the main part of this programme were completed in 1951 but a few extra stars have since been added at the specific request of individual astronomers. During 1955, 66 plates were taken, of which 44 were for parallax and 22 for the determination of proper motion. 112 plates were measured for parallax and 372 for proper motion in declination. Parallaxes were derived for the last two stars on the original programme of 1806 stars. There are still 2500 plates waiting to be measured which will provide second determinations of parallaxes for 67 of the stars previously measured. Some of these plates were measured during the year and new parallaxes were derived for 2 of the stars, but as the stars concerned are mainly stars with large and comparatively well known parallaxes, it is not intended to press on with the measurement of these plates until proper motions in declination have been derived for all the stars on the original programme.

At the request of Dr Gliese of the Astronomisches Rechen-Institut in Heidelberg, the places of 75 faint nearby stars were determined from existing parallax plates to within one second of arc, which is of sufficient accuracy to allow of their identification unambiguously.

Eros.—The measurement and reduction of the 46 plates of Eros which were taken with the Victoria Telescope during the 1954 opposition have been completed and the derived positions communicated to the appropriate authorities. About 12 reference stars per plate were used in order to reduce the effect of errors in their adopted proper motions and one of the interesting by-products of the investigation was the light it threw on the sizes of these errors. The proper motions from the Cape Astrographic Zone Catalogues, which were obtained by the differential measurement of two sets of photographic plates, are markedly superior as regards relative accidental errors to those in the more recent Cape and Yale Zone Catalogues which were obtained by comparing a photographic place with an earlier meridian place. This emphasizes once more the desirability of repeating the photographic zone observations.

Proper Motions.—83 plates were taken with the Astrographic Refractor in connection with the programmes suggested by the 1953 Groningen Conference for using existing astrographic material to find the proper motions of selected objects and of stars in a few specific areas. Some plates were measured experimentally, but the routine measurements for this programme have not yet been commenced.

Radcliffe Section.—583 spectra were obtained for the radial velocity programme and 630 were measured during the year. 1517 photoelectric observations in three colours of the fainter stars in the E regions were made with the Cassegrain photometer. 15 photographs of extra-galactic nebulae were taken at the Newtonian focus and one of an E region. Three nights were devoted to an effort to obtain spectra of bright regions in N.G.C. 253. Some success was achieved but it is quite clear that a faster spectrograph than the Cassegrain d-dispersion will be needed to obtain completely satisfactory spectra.

The observations for the 400 stars on the original radial velocity programme are now practically complete, but during 1955 extra stars from the Selected Areas and from the South Galactic Cap were added to the list. Two mimeograms giving preliminary results from the radial velocity programme were prepared and circulated to a number of astronomers likely to be interested.

A special study was made of p Velorum and an analysis of 56 spectra taken at Pretoria and 37 by the Lick observers is now almost complete. The effects of the orbital motion of the spectroscopic and visual pair have been disentangled.

Stellar Photometry.—Work on the *Second Bright Star Programme* which includes all stars in the Yale Bright Star Catalogue between $-4°$ and $-64°$ together with a number of fainter stars from the radial velocity and parallax lists continued steadily throughout 1955. 3010 two-colour observations were made for it on 92 nights with the photoelectric photometer attached to the Astrographic Refractor. By the end of 1955, magnitudes and colours had been derived for 640 stars, all of which had been observed at least four times. The internal standard errors of the resulting magnitudes and colours are $\pm 0^m{\cdot}008$ and $\pm 0^m{\cdot}006$ respectively.

3040 observations were made on 88 nights with the photoelectric photometer attached to the Victoria Refractor for the main E Region programme. This programme aims at providing observations in three colours (U, B and V) for the stars brighter than $10^m{\cdot}0$ and in two colours (B and V) for the fainter stars. The object of those observations is to strengthen existing data and to provide a strong overlap with the Pretoria observations of the fainter stars.

591 three-colour photoelectric observations were made on 24 nights with the Victoria Refractor of B type stars whose radial velocity and spectral type have been determined at the Radcliffe Observatory. Provisional photometric parallaxes have been derived for a considerable proportion of these stars using assumptions analogous to those made by Morgan, Johnson and Harris.

588 photoelectric observations were made on 16 nights with the Astrographic Refractor for the programme for determining U–B colours for stars brighter than $7^m{\cdot}0$ in the E Regions and of stars brighter than $3^m{\cdot}5$ distributed all over the southern sky.

102 pairs of plates were obtained with the Photometric Cameras for the programmes begun in December 1952. 60 of these pairs were for the two zone programmes and 42 for comparing the C Regions and the Kapteyn Selected Areas at $+15°$ with the E Regions at $-45°$. 35 400 images on 50 pairs of plates were measured with the Schilt Photometer, the plates for the $-66°$ to $-70°$ zone receiving first priority.

Variable Stars.—Mr R. P. de Kock continued the programme of observing long period variable stars which he began twenty-three years ago. During

1955, he made 5751 visual observations of 176 stars with the Six-Inch Telescope. He also kept a special watch on T Orionis and on two " flare " stars 013418 UV Ceti and 203501 AE Aquarii.

At the request of Dr B. E. Pagel, the photoelectric photometer attached to the Astrographic Refractor was used on 8 nights to make 335 two-colour observations of three bright early B-type stars with variable radial velocity in the hopes of detecting variability. β Crucis and 7^1 Lupi were found to have short-period variations in light with a range of about $0^m{\cdot}04$. 7^1 Lupi appears to be a typical small-amplitude β Cephei variable.

The same photometer was used on 4 nights to make observations of BL Telescopii.

Guest Investigators.—Professor John B. Irwin of the University of Indiana worked at the Observatory from February till July. He made a special study of the southern cepheid variables and obtained 2244 three-colour photoelectric observations with the Victoria Telescope of classical cepheids and comparison stars. These observations, which were spread over 40 nights, together with supplementary measures made at the Radcliffe Observatory, should give fairly good light curves for 100 southern cepheids brighter than the 13th magnitude at minimum and the median magnitudes, colours and colour excesses of perhaps 40 more.

Dr Halton C. Arp began a population study of the Small Magellanic Cloud with the Victoria Telescope in November. By the end of the year he had obtained 81 photographs in the U, B or V wave-lengths of the Cloud and of suitable comparison objects. He had also made 82 photoelectric measures of 22 stars in the Cloud and of 16 Johnson standard stars.

Mr D. Fernie, of the University of Cape Town, made a special study of the galactic cluster NGC 2547. He used the photoelectric photometer attached to the Victoria Telescope on 18 nights and obtained 448 three-colour observations of the brighter stars in this cluster. These data, supplemented by star counts on plates taken with the ADH Telescope at Bloemfontein, by magnitudes obtained photographically and by proper motions determined by comparing new plates of this cluster with existing photographs taken with the Astrographic and Victoria Telescopes many years ago, formed the basis of a thesis for which he was awarded an M.Sc. degree by the University of Cape Town.

Miscellaneous.—33 other plates, or plate pairs, were taken with the Victoria Telescope for various purposes during the course of the year. These included plates of various Kapteyn Selected Areas, of a number of variable star fields obtained at the request of the New Zealand observers and of a number of galactic clusters taken either for Mr Fernie, or for Dr Koelbloed of Amsterdam to supplement the material he collected during his visit to the Cape in 1954.

54 observations of 33 occultations were made with various telescopes at the Observatory. Of these 48 were disappearances at the dark limb, 4 reappearances at the dark limb and 2 disappearances at the bright limb.

The Sun was photographed on 342 days, two photographs being taken each day except six. All the photographic plates have been sent to Herstmonceux for measurement.

Armagh Observatory

(*Director, Dr E. M. Lindsay*)

The Director completed a catalogue of stellar-like emission objects in the Small Magellanic Cloud. 48 short exposure plates on comets and 123 exposures on variables were made with the Armagh Schmidt. FP, AX, RZ, HH, FQ, and FU Aur are covered.

Meteorological observations and reductions were carried out by Miss Grew.

Dr Öpik continued his theoretical investigations on the physical theory of meteor phenomena and the origin of meteors, concluded the statistical analysis of 26 000 meteor observations from the Arizona Expedition, and continued experiments in meteor photography. As in previous years he continued to be Editor of *The Irish Astronomical Journal*.

Contributions Nos. 14–16 and Leaflets Nos. 25–35 have been distributed. Contributions Nos. 14–16 and Leaflets Nos. 28–41 have been published.

Papers in press or completed are: *A Catalogue of Stellar-like Emission Objects in the Small Magellanic Cloud* by E. M. Lindsay; *Statistical Results from the Arizona Expedition for the Study of Meteors* by E. J. Öpik.

Mr F. E. Kameny completed a year at the Observatory in October and returned to the United States.

The Haffner iris-diaphragm photometer arrived in October; it is proving a very effective instrument.

Dr Lindsay and Dr Öpik attended the I.A.U. meetings in Dublin, small grants for expenses being made by the Royal Society. Some five hundred delegates and guests of the I.A.U. visited the Observatory. The Director gave a paper at one of the Society's meetings on *Emission Objects in the Small Magellanic Cloud showing Nebular Lines* (*M.N.*, **115**, 248, 1955) and lectured to the Physics Colloquium, Queen's University of Belfast, on *The Photoelectric Photometry of Variable Stars*. Dr Öpik lectured to the Dublin Institute for Advanced Studies on *Meteors and the Upper Atmosphere*.

The Director attended a meeting in Brussels and one in Dublin of the Administrative Council of the Boyden Station. The Council consists of the Directors of Armagh, Dunsink, Hamburg, Harvard, Stockholm and Uccle Observatories. At the Brussels meeting agreement was reached as to the future policy and maintenance of the Boyden Station, provisionally for the next two years. Harvard Observatory has relinquished its share in the ADH telescope which has now become the property of Armagh and Dunsink only; according to a clause, Harvard retains the right of usage of the instrument while it remains in South Africa. An anonymous donor has made a gift of £5000 which will meet some badly needed requirements of the ADH.

Cambridge Observatories

(*Director, Professor R. O. Redman, F.R.S.*)

Solar Research.—Dr von Klüber, in cooperation with Dr A. H. Jarrett of the St. Andrews University Observatory, has completed the measurement and discussion of interferometric photographs of the corona made in the light of the green 5303A line at the total eclipse of 1954 June 30. The results have

been communicated to the Society. A party consisting of Dr Jarrett and Dr and Mrs von Klüber went to Hingurakoda, Ceylon, to observe the eclipse of 1955 June 20, intending to repeat these corona measurements with a larger solar image, using the red 6374A line as well as 5303A. While in Ceylon Dr von Klüber gave assistance to a combined party from the St. Andrews University Observatory and the Potsdam Astrophysikalische Observatorium. The group under Dr von Klüber was also joined by Dr A. Dollfus of the Meudon Observatory. Owing to clouds, no results of scientific value were obtained.

Dr Blackwell has completed measurement and discussion of the corona photographs obtained by him from an aircraft at the 1954 eclipse and two papers have been communicated to the Society. The results have extended considerably our knowledge of the outer corona and have much reduced the present gap between corona and zodiacal light measures. At the 1955 eclipse Dr Blackwell made what proved to be an adventurous attempt to photograph the outermost parts of the solar corona, working from the air near Fiji, after the eclipsed Sun had set. The attempt was unsuccessful, partly because of engine failure, partly because of very bad weather, cloud extending considerably higher than the aircraft ceiling. On other days before and after the eclipse the zodiacal light was photographed from an altitude of 9000 ft., in excellent sky conditions, and the results should help considerably in extending the 1954 work.

Grateful acknowledgement should be made of help received from various institutions and individuals for the 1955 eclipse. Both Ceylon and Fiji expeditions were supported by grants from the J.P.E.C. The Ceylon group was assisted greatly by Professor A. W. Mailvaganam and other helpers from the University of Colombo. The flights from Fiji were made possible by the cooperation of the R.N.Z.A.F. On his way home from Fiji Dr Blackwell spent three weeks visiting U.S. observatories, assisted by grants from the Royal Society and the University.

Dr von Klüber has discovered that the large Babcock grating, mentioned in last year's report, allows remarkably clear visual observations of a fine structure of Fraunhofer lines, consisting chiefly of local Doppler shifts associated with the solar granulation. The effects are most conspicuous in Hα, but are to be seen in varying degree in nearly all lines of the solar spectrum. (The phenomenon was discovered independently at the McMath Hulbert Observatory, whose excellent photographs excited considerable interest at the Dublin I.A.U. meeting). The fine structure has been examined visually by Mr Beggs and Dr von Klüber, using an electro-optical shutter of the A.D.P. type, to find whether local magnetic fields could be detected, but nothing recognizable has been found.

Preliminary optical tests for the Babcock magnetograph, now under construction in the Observatories workshop, have been carried out. Mr Beggs has completed much of the electronic equipment required for this instrument.

Mr N. Boersma, of the Amsterdam Astronomical Institute, spent some weeks of the summer in Cambridge, and during his stay obtained a set of spectrograms of a sunspot showing a very large magnetic field with an unusual Zeeman pattern.

Mr D. V. Thomas has completed his work on the excitation (rotational) temperature of the chromosphere from the intensity distribution in the CN band at 3883A. Further investigation has shown that the errors of this method

are rather high; the chief troubles are self-absorption, which is difficult to assess quantitatively, the rather uncertain level of the continuous spectrum, and large numbers of blends. Mr Thomas has commenced an examination of the wings of strong chromospheric lines, particularly of H and K, at low levels.

The work by Mr Argue towards recording the infra-red spectra of prominences has been interrupted by the structural alterations at present being made to the Solar Physics Building.

Drs Blackwell and Dewhirst, with the cooperation of the R.A.F. (arranged through the Royal Society), have made four flights in a Lincoln aircraft, photographing the Sun through an open door, using a 7-in. refractor. The results show that the much needed high resolution photographs of the photosphere are unlikely to be obtained from conventional aircraft, partly because of vibration, but still more because of the air disturbance set up by the machine itself.

Dr von Klüber and Dr Fellgett in cooperation with Messrs Pye Ltd. have carried out experimental tests in examining the solar spectrum by a television technique, with encouraging results.

17-in. *Schmidt telescope.*—Dr Dewhirst, assisted by Mr Yates and Mr Argue, has continued the search for discrete radio sources, using the positions, made available before publication, of the 1936 sources of the Cavendish Laboratory's 2C catalogue. With blue-sensitive plates showing stars down to about $18^{m}{\cdot}5$ a few faint galaxies have been detected whose positions agree with intense small diameter radio sources, but otherwise no peculiar stellar or extra-galactic object has been found in the positions given. Photographs in the blue, and with a plate-filter combination for Hα, have given no evidence to support the idea that either H II regions or clusters of galaxies are responsible for the majority of large diameter sources. Workers at the Cavendish Laboratory have found a significant correlation between the positions of radio sources and those of nebulae in the N.G.C. or I.C. Photography of a selected number of suspected galaxies from these catalogues has shown that some have peculiar structure or are members of small clusters. It has become necessary to interpret coincidences between optical and radio objects with a good deal of caution, because of the comparatively large number of discrete radio sources now known. The fact that such coincidences as are found are often with fainter radio sources of uncertain position is itself a warning.

In cooperation with the Royal Greenwich Observatory Dr Dewhirst has started an investigation into the suitability of Schmidt-type telescopes for astrometry. A modification of the conventional method of standard coordinates has been developed for the case of a classical Schmidt system, in which two cubic terms due to the sphericity of the focal surface and the elastic distortion of the plate are first removed by tabular correction of the measured coordinates, before proceeding to a solution for plate constants. The general procedure appears to be satisfactory and the mean error of a star place from a single plate is about $0''{\cdot}3$ in each coordinate, the focal length being 64 in.

Mr Yates has designed an iris-diaphragm photometer for use with plates from the Schmidt telescope. Some progress has been made in its construction, although it has had repeatedly to give way to other more urgent demands on the Observatories workshop.

36-in. *reflector.*—The last stage of the re-equipment programme, started about seven years ago, was reached during the summer with the erection of the

36-in. reflector. This telescope, constructed by Messrs Grubb Parsons, has been designed for use either at the prime focus, at f/4·5, or at a fixed coudé focus, to which the light travels along the polar axis northwards, using a three-mirror combination giving f/18 or f/30.

Adjustment and testing of this instrument commenced in August. It has proved possible to adjust the R.A. drive to give a periodic error of not more than 0″·25 amplitude. A number of small modifications have been made, or are shortly to be made, following the first few months' experience. A matter of considerable interest has been the poor seeing arising in the dome and telescope. A first examination of star images showed diameters rarely less than 4″–5″, while extra-focal images and knife edge tests indicated that a good deal of trouble arose in the telescope itself. The introduction of strong down ventilation in both dome and tube led to a quite surprising improvement, image diameters often falling below 1″. Experiments are continuing.

Mr Yates has designed a photoelectric stellar photometer for use at the coudé focus of the telescope. The photometer embodies a 2-prism quartz monochromator and allows simultaneous measurement of the brightness of a star in three wave-length regions which may be selected at will. As in earlier photoelectric photometry carried out by Mr Yates, the receiver is a photo-multiplier used with a pulse-counting technique, in this case with trochotron and dekatron counters. The photometer is complete and is now being brought into adjustment by Mr Beggs and Mr Willstrop.

Dr Fellgett has continued the construction of the multi-channel infra-red spectrometer, which is now essentially complete. Testing has been held up by the reconstruction of laboratory space in the Solar Physics Building. This instrument also will be used at the coudé focus of the 36-in. reflector.

Optics.—Dr Linfoot has made further progress in the problem of developing assessments of optical image quality which are related in a satisfactory manner to intuitive notions of image quality on the one hand and to the design data of the optical system on the other. The key to the general theory appears to lie in the combined use of polychromatic transmission factors (sine-wave response functions) and of a modified ikonal function essentially due to E. Wolf. The ikonal function provides a suitable analytical link with the design data of the system, while the transmission factors characterize concisely the combined effects of aberrations (including chromatism) and diffraction on the image of a point source and of an extended object. The theory supplies, in terms of transmission factors, criteria of quality optimization in an optical design, corresponding to certain specified desirable properties of the image. The need for criteria of this type has been felt for some years by those interested in the electronic assessment of optical images.

Lansraux and Duffieux's work on " distant diffracted light " has been extended and a critical discussion made of their proposed criteria of the quality of diffraction images. The conclusion is that these criteria are only applicable when " edge diffraction effects " are first substracted, and only useful in cases where ray optics is already a sufficient approximation.

With the cooperation of Mr G. Black of the Computing Machine Laboratory of the University of Manchester, monochromatic transmission factors corresponding to selected amounts of spherical aberration at selected focal settings have been computed; they are being used to discuss the effects of spherical

undercorrection on the discriminating power of an optical system (or, what is equivalent, on its information passing capacity) and to rediscuss, on a more realistic basis, the position of " best " focus in the presence of spherical aberration, and the tolerance for spherical aberration in a practical optical system.

An 8-in. glass-on-steel flat mirror has been successfully figured and aluminized, preparatory to testing its thermal distortion under actual observing conditions. The aluminizing was kindly done by the Royal Greenwich Observatory. The thickness of the glass is 0·01 in., of the steel 1 in., and of the plastic cement between them 0·001 in. Experiments in making optical flat mirrors of chromium plated steel have not so far been successful; the first attempt failed because of laminated structure in the chromium plating.

Work has been resumed on the corrector plates of the 12–15 in. two-plate Schmidt Cassegrain system.

Dr Linfoot's book *Recent Advances in Optics* (Clarendon Press) appeared in May.

Other work.—A discrepancy between the electron densities derived for the Orion nebula by optical and radio measures respectively has led Mr Argue to measure the apparent brightness of the nebula in Hα, using the Schmidt telescope. Suitably calibrated photographs have given the isophotes in the brighter part of the nebula, but with the data in hand the conversion of the integrated brightness to absolute units can be carried out only with an accuracy of about 10 per cent. It appears fairly certain that the surface brightness in Hα is considerably affected by self-absorption.

Dr Beer has completed the analysis of all available data on spectroscopic binaries, with special regard to their masses. He is at present studying the spectrum of the peculiar A type star θ'Mic, using spectrograms kindly lent by the Radcliffe Observatory.

The first volume of *Vistas in Astronomy* (Pergamon Press) has appeared and the second will follow shortly. The work is edited by Dr Beer and is dedicated to Professor Stratton, Emeritus Professor of Astrophysics and formerly Director of the Observatories.

Library.—The library now possesses substantially complete sets of most astronomical periodicals, good progress having been made in filling important gaps from the war years. Thanks are due to the many individuals and institutions who have been helpful in this matter.

Colloquia.—The Observatory Club held 12 colloquia during the year. Among the speakers were Dr E. G. Bowen (Sydney), Dr R. M. Goody (London) and Professor J-C. Pecker (Clermont-Ferrand).

A symposium on Astronomical Seeing was held at the Observatories on September 12–14.

Dr Linfoot attended as an invited speaker a Symposium on the Evaluation of Optical Images held at Rochester N.Y. in June. He and Dr Fellgett also took part in the Manchester Symposium on Astronomical Optics in April. Dr Dewhirst was a speaker at the Hamburg-Bergedorf Observatory's Conference on Schmidt telescopes, in August, and also at the Radio Astronomy Symposium at Jodrell Bank.

Staff.—Mr G. G. Yates resigned his post as a Senior Observer at the end of October, to join the University's Department of Physical Chemistry as

a Technical Officer. Dr P. B. Fellgett joined the staff as a Senior Observer from October 1.

Cavendish Laboratory

(*Director, Professor N. F. Mott, F.R.S.*)

I. SOLAR

(*a*) *The general magnetic field.*—A series of observations has been made near the minimum of the sunspot cycle, to detect a general magnetic field at coronal levels (**1**). Such a field would produce a small circularly-polarized component of the emitted radiation, whose sense would be opposite for the two hemispheres. An earlier attempt to detect this component by observations during a partial eclipse was made by Christiansen, Yabsley and Mills (**2**).

The present observations, at a wave-length of 60 cm achieved a greater sensitivity by using an interferometric polarimeter consisting of two aerials with opposite polarization separated at various spacings along a North–South line. At a spacing of about 100λ the contributions of opposite polarity from the North and South hemispheres combine to produce a deflection at the output of a phase switching receiver.

Using this instrument, an upper limit of 0·25 per cent could be fixed for the magnitude of the polarized component. The derivation of the magnetic field corresponding to this degree of polarization depends on the temperature and density in the lower corona, and on the assumed form of the magnetic field; a preliminary estimate based on a dipole field leads to an upper limit of 2·5 gauss for the surface field at the poles.

(*b*) *The outer corona.*—Further investigations of the region 5–20 R_0 have been made by observing the occultation of the Crab nebula during 1955 June. The results obtained confirmed those of previous years (**3**) in showing that the degree of scattering is asymmetrical about the point of closest approach; the scattering in every case is greater when the Crab nebula is receding from the Sun. In view of the Sun's position angle, this could be caused by a non-spherical distribution of the scattering irregularities, with a larger extension in the equatorial direction.

The recent results have also indicated that the scattering is very much greater when the source is situated behind the polar regions of the corona; it is thought that the irregularities in these regions may be of a different type from those occurring at low heliographic latitudes.

(*c*) *Routine observations.*—Regular observations have been maintained of the intensity of the solar emission on wave-lengths of 1·7 m, 3·7 m, and 7·9 m.

II. LUNAR OCCULTATIONS OF RADIO STARS

Observations have been made (**4**) at wave-lengths of 3·7 m and 7·9 m of the lunar occultation on 1955 April 26 of the galactic nebulosity IC 443 (source number 2C.537 of the Cambridge survey (**5**)). The results suggested that the radiation originated mainly in the regions of strong Hα emission.

By relating the time at which a well defined filament was uncovered by the Moon's limb with that of a sudden increase of received intensity, it was also possible to derive a maximum value for the refraction of the radio waves in the

lunar atmosphere. The observations indicated that the density of the sunlit lunar atmosphere is unlikely to exceed 10^{-12} of that of the terrestrial atmosphere at sea-level.

Observations have also been made of the lunar occultation of the Crab nebula on 1955 November 30 and 1956 January 24 (**6**). These enabled the distribution of radio brightness across the nebula to be derived in detail at a wave-length of 3·7 m. The smaller angular size and greater intensity of this source meant that an even lower limit could be set to the refraction in the lunar atmosphere. The new observations showed that even on the sunlit limb the refraction was less than 15 sec of arc. This figure corresponds to a maximum density about 10^{-13} of that of the terrestrial atmosphere.

III. RADIO STARS

After the completion of a survey of radio stars at a wave-length of 3·7 m (**5**) the large radio telescope was used for a number of subsidiary observations to check the conclusions previously reached on the apparent spatial distribution of the radio stars (**7**).

The operating wave-length of the instrument has now been altered to 1·9 m for a new series of observations.

Further searches for optical identifications have been made, both by Dr Minkowski on the plates of the 48″ Sky Survey, and by Dr Dewhirst who has made some special observations with the Cambridge Schmidt Camera.

These searches have proved remarkable for the small number of conclusive identifications; a number have been found near the positions of faint extra-galactic nebulae, but most of these require confirmation by spectroscopic observation with large telescopes. In one case Dr Minkowski has reported the object appears to be a further example of galaxies in collision; the distance of this object is 100 mps, even greater than that of the colliding galaxies in Cygnus.

This observation and the failure to detect, optically, sources whose positions are known with some accuracy lends further support to the conclusion that the majority of radio stars are extremely rare extra galactic sources having a radio luminosity comparable with that of the Cygnus source (**7**).

Attempts have been made to detect emission at wave-lengths of 3·7 and 7·9 m from Jupiter. In both cases the apparatus had a considerably greater sensitivity than that used elsewhere at longer wave-lengths for the successful observation of the radiation. No variable source of radiation was found, and it was concluded that the spectrum of the radio emission from Jupiter must vary at least as fast as $\lambda^{5\cdot5}$ (**8**).

IV. THE GENERAL RADIATION

(*a*) *The spherical "halo" of radio emission.*—A survey of the general radiation has been made at a wave-length of 3·7 m (**9**), and the results have been discussed by Baldwin (**10**). The new data can be used to fix an upper limit to the intensity of the extra-galactic radiation, and also show that over 85 per cent of the galactic emission originates in a nearly spherical region having a radius which lies between 11 and 14·5 kps. Within this sphere the emission per unit volume shows little radial variation and has a value of about $1{\cdot}8 \times 10^{8}$ w. ster^{-1} (c/s)$^{-1}$ ps^{-3}. Earlier observations of the Andromeda nebula

(**11**) indicated that it possessed a similar spherical region, having a radius of about 18 kps and an emission of only $0{\cdot}3 \times 10^8$ w. ster^{-1} (c/s)$^{-1}$ ps^{-3}.

Observations of the peculiar galaxy M87 have also been made to investigate the extensive " halo " associated with it (**12**). Measurements at a wave-length of 3·7 m showed that the halo, which contributes about 25 per cent of the total radio emission has the remarkably large radius of 65 kps.

The possibility of accounting for the emission from these regions in terms of the radiation from relativistic electrons moving in weak but extensive magnetic fields has been explored (**13**).

(*b*) *Possible radio emission from the galactic nucleus.*—The intense source in the direction of the galactic centre has been studied at wave-lengths of 7·9, 3·7, 1·9 and 1·4 and 0·6 m using systems of large resolving power (**14**). It is found that at these wave-lengths the flux density increases with frequency, and that at 7·9 and 3·7 m the brightness temperature is greatly in excess of the normal electron temperature in an H II region. The observations indicate the presence of a non-thermal source, which may well be situated in the nucleus of the galaxy, lying behind a group of H II regions which are probably largely responsible for the emission observed at shorter wave-lengths.

(*c*) *Survey at a wave-length of 7·9 m.*—A new type of " pencil-beam " radio telescope, based on the combination of a long narrow aperture and a small moving aerial, has been constructed. The new instrument, which operates on a wavelength of 7·9 m has a resolving power of $2\frac{1}{2}^\circ$ and is being used to derive the distribution of the background radiation at this wave-length (**15**).

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(**2**) Christiansen, W. N., Yabsley, D. E. and Mills, B. Y., *Aust. J. Sci. Res.*, **2A,** 506, 1949.
(**3**) Hewish, A., *Proc. Roy. Soc.* A, **228,** 238, 1955.
(**4**) Elsmore, B. and Whitfield, G. R., *Nature*, **176,** 457, 1955.
(**5**) Shakeshaft, J. R., Ryle, M., Baldwin, J. E., Elsmore, B. and Thomson, J. H., *Mem. R.A.S.*, **67,** 1955.
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(**12**) Baldwin, J. E. and Smith, F. G., *Observatory*, **76,** 141, 1956
(**13**) Burbidge, G. R., *Ap. J.*, **123,** 187, 1956.
(**14**) Smith, F. G., O'Brien, P. A. and Baldwin, J. E., *M.N.*, (in the press).
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University Observatory, Glasgow

(*Director, Professor W. M. Smart*)

Dr A. E. Roy and Dr M. W. Ovenden have published a paper relating the observed distribution of mean motions in the solar system to certain periodic solutions of the *n*-body problem (*M.N.*, **115,** 296, 1955). Dr Ovenden is investigating the bearing of these results upon the significance of the laws of planetary distances.

Dr Ovenden has also been reducing and discussing his photoelectric observations of the eclipsing binary TX Cas.

Dr Tannahill is investigating the motions, relative to the Sun, of the stars in the spectral group B8–A4, from the radial velocities listed in R. E. Wilson's *General Catalogue of Stellar Radial Velocities*. The solutions so far achieved reveal systematic differences in the parallactic motion from the spectral sub-groups. Solutions from the north and south galactic hemispheres separately show an apparent difference (mainly in the Z-component) of about 3·5 kilometres per second; this difference is now being carefully examined. Work on a comparison of the Boss General Catalogue and the Cape Zone Catalogues is progressing slowly.

Dr D. G. Ewart has published his investigation " On the Relation between the Stream and the Ellipsoidal Constants " (*M.N.*, **115**, 47, 1955), and a paper entitled " Note concerning the Constants of the Velocity Ellipsoid from the Radial Velocities of 820 Stars " is being published by the Society.

During the year Dr Ovenden has been awarded the Ph.D. degree of the University of London for a thesis entitled *Two-colour Photoelectric Photometry of Eclipsing Variable Stars*, and Dr Ewart the Ph.D. degree of the University of Glasgow for a thesis on *Stellar Kinematics*.

University of London Observatory

(*Director, Professor C. W. Allen*)

Parallax.—The parallax programme has been brought to an end with the third list of parallax results containing 17 stars. Plates for two of the stars were measured with a Hilger microphotometer by Mr T. Kiang.

Minor planets.—Dr R. H. Garstang has obtained 8 positions of minor planets from plates taken in 1954 and 1955. Results were sent to the Minor Planet Circulars.

Laboratory spectroscopy.—Mr E. W. Foster has measured absolute transition probabilities for several O I lines using a vortex stabilized arc in steam. Attempts are being made to determine whether the transition probabilities depend on conditions in the arc. Mr A. S. Asaad has measured oscillator strengths on a standardized (and approximately absolute) scale for 450 lines in the spectra of Cr I, Mn I, Fe I, Cr I, Ni I, and Cu I using as source the arc between dilute copper alloys.

Stellar spectra.—In his study of the red region of stellar spectra Dr Garstang has measured the equivalent widths of many lines in 9 Pegasi.

Solar eclipse of 1955 June 20.—An expedition consisting of Mr E. W. Foster and the Director was sent to Polonnaruwa, Ceylon, for the purpose of making photometric and spectroscopic measurements of the outer corona. No results were obtained as the eclipsed Sun was obscurred by dense cloud throughout totality.

Use of instruments.—It has been realized for about a year that there has been a deterioration of the star images of the Radcliffe 24-inch photographic lens. This was apparently due to some relative movement of the two components of the doublet. The lens is now under test and being readjusted. The Wilson 24-inch and smaller instruments have been used by students and visitors.

Theoretical work and analysis.—Dr P. A. Sweet is deriving a model for rapidly rotating stars and is also examining the equations governing the behaviour of gas clouds in interstellar magnetic fields. Dr R. H. Garstang has continued his investigations on the computation of the transition probabilities of lines. Calculations on the ions [Ni III] and [Fe V] were completed, work on [Fe III] was continued, and methods were studied with a view to future work on [Ni II] and [Fe II]. The effect of configuration interaction on the transition probabilities of forbidden lines was examined, and the present status of calculations on auroral lines was reviewed. The Director and Mr A. S. Asaad have studied large differences between calculated and observed oscillator strengths of lines of the iron group of atoms, and shown how the differences are related to excitation potential.

Publications.—The following books and papers have been published during the year.

C. W. Allen, *Astrophysical Quantities*, Athlone Press, London, 1955.

C. W. Allen, " A System of quantitative astronomical observations " *Vistas in Astronomy*, p. 149, 1955.

C. W. Allen, " Whole-sky statistics of celestial objects ", *M.N.*, **114**, 387, 1954.

P. A. Sweet, " The structure of sunspots ", *Vistas in Astronomy*, p. 675, 1955.

P. A. Sweet, " Field reversal in magnetic variable stars ", *M.N.*, **113**, 549, 1955.

R. H. Garstang, " The calculation of atomic transition probabilities ", *Vistas in Astronomy*, p. 268, 1955.

R. H. Garstang, " Stellar populations ", *J.B.A.A.*, **65**, 122, 1955.

R. H. Garstang, " Isotopes in astronomy ", *J.B.A.A.*, **65**, 371, 1955.

T. Kiang, " Colour excess of B-stars and the inner spiral arm ", *Ann. d'Ap.*, **18**, 76, 1955.

T. Kiang, " Parallax measurement with a recording microphotometer ", *The Observatory*, **75**, 227, 1955.

V. C. Reddish, " Colour-magnitude arrays in the clusters Tombaugh 5, N.G.C. 7789, 1528, and 2682 ", *M.N.*, **114**, 583, 1955.

V. C. Reddish, " The masses of stars of population II ", *M.N.*, **115**, 32, 1955.

Staff and students.—Mrs M. K. Beacham replaced Mrs J. M. U. Armstrong as confidential clerk in February, Mr E. P. Hayne replaced Mr R. V. Thornton as technician in December.

Since October there have been ten undergraduate students taking regular lecture courses or practical astronomy and one postgraduate student.

Visitors.—There were 372 afternoon and evening visitors to the observatory during 1955.

Radar Research Establishment, Ministry of Supply, Malvern

The radio line emission equipment has just been brought into operation at 327 Mc/s for the purpose of measuring the deuterium line intensity in the galaxy. Owing to intermittent external interference it has not been possible to utilize the long integration times of several hours originally contemplated. In a preliminary series of observations with an aerial of 25 ft diameter, the apparatus has been arranged to integrate over successive intervals of 5 minutes as the aerial beam passed through the centre of the galaxy in which direction

the line may be expected to appear in absorption. Although the sensitivity achieved is estimated at better than 1°, there has so far been no clear evidence of the line. The experiment is proceeding, and with a longer series of observations and a 45 ft diameter aerial which should be available later this year (1956), it is hoped to obtain precise measurements of the deuterium line intensity.

The analysis of the E–W asymmetry in solar flares and associated radio bursts has been completed (**1**). The 1954 June 30 eclipse observations at $\lambda = 10$ cm are in publication (**2**); the results indicated more extensive emission in the equatorial plane than at the poles. The 10 cm radiometer is now being used with an interferometer aerial system for continuous observation of sunspots.

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(2) Hey, J. S., and Hughes, V. A., "Centimetre Wave Observations of the Solar Eclipse of 1954 June 30", *The Observatory*, **76**, 1956.

Jodrell Bank Experimental Station, University of Manchester

(*Director, Professor A. C. B. Lovell, F.R.S.*)

The radio telescope.—The constructional work on the radio telescope continued satisfactorily during 1955. At the time of the last report (December 1954) part of the steel work, including the two main towers, had been erected to a height of 140 ft above ground level. During 1955 the whole of this tower structure was completed (to a height of about 180 ft above ground), and all the bogies were in position including the four driving bogies and eight wind bogies. One of the main trunnion bearings with its associated steel work and driving rack was successfully mounted during the autumn, and before the end of the year two of the sixteen ribs which form the paraboloidal bowl were in position. It is now expected that the steel work for the bowl will be completed by the early Summer of 1956, and there are good grounds for anticipating that the preliminary tests may begin on the telescope towards the end of the year. The manufacture of the control console and associated instruments is nearing completion and part of this apparatus was tested during the summer of 1955. The control building was also finished during the year, and is now in use.

Galactic and extra-galactic radio emissions. (i) *92 Mc/s survey.*—Following the completion of the 158 Mc/s survey, a new survey is being carried out at 92 Mc/s using the 218 ft paraboloid. This is being performed simultaneously with the 158 Mc/s interferometer programme. At 92 Mc/s, the beamwidth of the aerial is about 3° between half power points, as compared with 2° at 158 Mc/s. The broader beam, combined with the electrically operated mast tilting system, has enabled the field of view of the instrument to be extended to zenith angles of about ±25° (declinations 28° N to 78° N). This covers about 20 per cent of the celestial sphere, which is approximately twice the area surveyed at 158 Mc/s. The efficiency of the parabolic reflector at 92 Mc/s is greater, feeder losses are smaller, and receiver performance is improved

compared with 158 Mc/s. In addition, the spectra of radio sources are such that they are in general more intense at the lower frequency by a factor of about 2. It is therefore expected that the number of sources detectable in the new survey will be considerably greater than in the previous one.

A general survey of the field of view is being carried out in a search for discrete sources. Approximately one-fifth of this programme has been completed. Over restricted regions around interesting optical objects, more detailed observations are being made with particular attention to the extra-galactic nebulae, singly, in clusters, and large-scale aggregations. Comparison with records from the 158 Mc/s survey is expected to reveal more detail in both the general and the detailed investigations.

The extended field of view has led to the tentative identification of a radio source with the Great Loop in Cygnus (**1**) (zenith angle 23°). The observed source agrees well with the Loop both in position and extent, particularly in the light of recent 48-inch Schmidt photographs which reveal extensions of the Loop unobserved previously.

(ii) *The low frequency spectrum of Cygnus and Cassiopeia.*—The low frequency spectrum of the intense sources in Cygnus and Cassiopeia has been investigated by using the 218 ft transit telescope at frequencies of 16·5, 19, 22·6 and 30 Mc/s. The experiment is difficult to carry out because of interference from long distance ionospheric scatter transmissions, but successful measurements were made during transit of the sources at night in the summer of 1955. The main feature of the results is the abrupt fall in intensity of both sources below 22·6 Mc/s. It has been shown that the most likely cause of this decrease in intensity is absorption in interstellar H II regions (**2**).

(iii) *Diameter of the radio stars.*—The construction of a high resolution phase-sensitive interferometer has been completed and the instrument is now in operation. The interferometer was designed for the determination of the distribution of intensity across the intense sources in Cygnus and Cassiopeia. It operates on a frequency of 127 Mc/s and uses three stations. Two of the stations are mobile and are equipped with radio links, whilst the third is at Jodrell Bank.

Measurements with the instrument so far have covered the range 200–2000 λ East–West and have confirmed the bifurcation of the Cygnus source, as previously determined by the post-detector correlation interferometer (**3**). A detailed study of the Cassiopeia source is in progress.

The rotating-lobe interferometer (**4**) has continued to operate at 158·5 Mc/s in conjunction with the 218 ft transit paraboloid and a small mobile aerial. A coherent radio link between the two receivers has been in use since early this year. As forecast in the last report, the technique has made it possible to observe weak discrete sources of very small angular diameter. Three such sources within the field of the transit paraboloid have been studied, using base lines up to 10 000 λ (20 km). One of these sources is certainly unresolved at the longest base line, so that its angular diameter is less than 15 seconds of arc. The apparent surface temperature of this source is therefore of the same order as the temperature of Cygnus A ($\sim 10^8$ deg. K). The rotating-lobe technique has provided a more accurate measurement of the declination of this source, with errors of about ± 5 minutes of arc. The other two sources appear to have diameters between 15 minutes and 25 minutes.

(iv) *Polarization.*—At the end of 1954 the light from the Crab nebula was reported to be polarized appreciably. The rotating-lobe interferometer which was developed for the measurements of the diameter of radio stars was therefore adapted in 1954 December and 1955 January to test for linear and circular polarization of the radio emissions from Cassiopeia A, Cygnus A and Taurus A. The aerials used were a 30 ft paraboloid, and a 25 ft paraboloid, with crossed dipole feeds. No polarization effects were detected. These measurements reduced the upper limits assigned by previous workers to less than 2½ per cent linear polarization and to less than 4 per cent circular polarization (**5**).

Wind movements in the F region of the ionosphere.—The modification of the three station equipment for the measurement of F region drifts by the radio star scintillation technique has been completed and routine observations were started in October. It has now been confirmed (**6**) by spaced receiver experiments that the ionospheric irregularities causing radio star fading are elongated along the lines of magnetic force (axial ratio about 5 : 1) and that the three station observations yield only the component of horizontal velocity in the direction of the minor axis of the elliptical diffraction pattern on the ground. However, alternate observations on two radio sources separated in R.A. by $3^h\,24^m$ have made possible the determination of "true" velocities by compounding the components measured in two directions. (Horizontal motions are assumed: neither speed nor direction would be true if there were vertical motions). Some preliminary results were obtained on four nights in October and November: these showed a predominant motion towards the S.W. between 20^h and 24^h which is in agreement with other F region drift determinations in winter. It is planned to make a more systematic investigation in the summer of 1956 when the sources again transit at night.

A continuous observation of the radio star in Cassiopeia has been made since 1954 June and a year's results are now being analysed for temporal variations in scintillation rate and amplitude. A detailed analysis has been made on certain days for comparison with magnetograms from Lerwick. This investigation has revealed a very close correlation between the variation in scintillation rate and magnetic disturbance.

One theory of the origin of the irregularities causing radio star fading is that they are due to turbulent winds in the F region (**7**). This is now believed to be untenable since movements of the ionization in the F region due to winds would be subject to strong electromagnetic damping. The observed movements are now believed to be due to the interaction of electric fields and the Earth's magnetic field, the electric field being set up by winds in the lower ionosphere and communicated to the F region along the highly conducting lines of magnetic force. It is suggested that the irregularities are caused by turbulent winds in the lower ionospheric regions imposing on the electric field a component due to turbulent velocities which, on being transferred to the F region, causes the ionization to drift into irregular patches. The electronic recording of the variations in the east–west component of the Earth's magnetic field was recommenced in October.

The 21 cm interstellar hydrogen line.—The original measurements (**8**) of the distance of the radio stars, obtained from their absorption at 1420 Mc/s, have been repeated using an improved receiver (**9**). The source in Cygnus (19N 4 A) lies outside the Galaxy whereas that in Cassiopeia (23N 5 A) appears

to lie between the outer two spiral arms at a distance of about 3 kiloparsecs. The latter result is at variance with the optical results of Baade and Minkowski (1954) who place the source at about 500 parsecs. The distance of the source in the direction of the Galactic centre (17 S2A) was measured by two independent methods (**10**) and found to be about 3 kiloparsecs. It is suggested that this source may be an H II region illuminated by a group of early-type stars at this distance.

The 21 cm emission from neutral hydrogen has been studied in the direction of several dust clouds in the galactic plane. The observed temperature is found to be lower than in surrounding unobscured regions. This appears to be due to neutral hydrogen which is cooler and more dense than nearby hydrogen. The kinetic temperature was calculated to be from 60 to 70 deg. K. This result confirms the earlier observation that the kinetic temperature in the direction of the radio sources in Cygnus and Cassiopeia may vary markedly from the generally accepted value of 125 deg. K.

Aurorae.—Radio echo observations of aurorae have continued throughout 1955 on both the fixed and rotating aerial meteor survey equipments. Although echoes were observed on only five occasions during the year this showed an increase on 1954.

Eskdalemuir magnetograms for all days since 1949 on which radio echoes were obtained showed moderate to intense disturbances. A statistical study from the magnetograms of the change in vertical component of the Earth's magnetic field (V) showed a diurnal variation which changed in sign at about 2130 U.T., being positive before and negative after this time. The change from positive to negative disturbance at about 2130 U.T. coincides in time with a reversal in the direction of motion of the radio reflecting regions from East to West, to West to East and also with a minimum in the radio echo diurnal frequency distribution. It has been found that as a rule diffuse type echoes in the evening coincide with positive bay disturbances in the horizontal components of the Earth's magnetic field (H) and discrete echoes in the morning with negative bay disturbances (**11**), (**12**), (**13**).

Meteor survey.—The continuous meteor survey equipment has been in operation throughout the year and observations on all the major meteor showers were successfully made. A new transmitter for the rotating aerial experiment was brought into service in 1954 December and equipment has operated at full sensitivity throughout the year. The large fireball widely observed in Britain on the evening of 1955 March 24 was detected on both equipments. The echoes recorded were rather weak, but the observed range of 520 km corresponds well with the path of the fireball computed by Dr J. G. Davies from visual reports.

Meteor orbits.—The three-station technique for delineation of the orbits of individual meteors has been in use since early 1954. In twelve 24 hour periods, one in each month from 1954 May to 1955 April, about 2400 sporadic meteor orbits have been measured (**14**) (**15**). Most of these meteors are of magnitude +7 and +8, and about one quarter of them move in orbits of periods of about one year and eccentricities less than 0·5. The inclinations of these orbits are all greater than 20°, and show concentrations in inclinations at 60° and 140°. No case of a definitely hyperbolic orbit has been found. The accuracy of the method has been shown to be limited by atmospheric effects to $\pm 3°$ in

radiant position and ± 2 km/sec in velocities. The technique has also been applied to a number of showers during the year.

Meteor physics.—The mass distributions of shower and sporadic meteors have been investigated (**16**). The frequency of sporadic meteors is found to increase by 2·5 times per magnitude over the range 0^m to $+10^m$, corresponding to equal total masses in each magnitude. In the case of showers, no single law was found to hold over the whole range. For example, the greater part of the total mass of the Arietid shower lies in meteors fainter than $+7^m$ whereas the mass of the Quadrantid, Perseid and Geminid showers shows a concentration in the range $+2^m$ to $+7^m$. The work on the polarization of radio echoes from meteor trails has now been completed (**17**) (**18**), and further information has been published about the measurement of upper atmospheric scale heights and densities using the radio echo technique (**19**).

Meteor photography.—The meniscus Schmidt meteor camera, which was made at the University of Bristol, was installed at Jodrell Bank in April. The camera has been used during the Perseid and Geminid meteor showers in conjunction with a radio-echo height-finding equipment. Seven meteors were photographed during the Perseid shower in August in spite of a poor batch of photographic emulsion which was between 2 and 3 magnitudes slower than anticipated. Four of these photographs had correlated radio echoes, which were unfortunately poor owing to the position of the meteor trails in the aerial polar diagram. Two Geminid meteors were photographed and both of these have correlated radio echoes.

The problem of coating the spherical photographic plates for the camera with a uniform layer of emulsion, without loss of sensitivity, has been investigated with the cooperation of Kodak, Ltd., and a satisfactory solution is now in sight.

The future programme for this camera involves simultaneous recordings with the radio echo height finding equipment to investigate the relationship between the luminous and ionizing efficiencies (**20**) in meteor trails, and other problems concerning the evaporation of meteors.

Upper atmosphere winds.—The wind measurements at a mean height of 95 km, using radio echoes from meteor trails, have continued (**21**). The results obtained during 1955 are in good agreement with those of the preceding year. In particular the seasonal phase and amplitude variations of the semi-diurnal periodic wind component have been confirmed during the second year. The prevailing wind also undergoes similar variations in the two years, blowing towards east in summer and winter, and towards west in spring and autumn.

In addition to the routine observations at a fixed height, a detailed investigation of the variation of wind velocity with altitude between 80 and 100 km has now been carried out. The amplitude of the semi-diurnal wind component is found to change by 1 to 2 m sec^{-1} km^{-1}, increasing from 15 m sec^{-1} at 85 km to 40 m sec^{-1} at 100 km. The phase of the 12 hour rotation of the wind vector also varies with height by approximately 6 degrees km^{-1}. The wind blows towards north at 0400 and 1600 h at a height of 100 km, and at 0700 and 1900 h at 85 km throughout most of the year.

Gradients of -1 to $+1$ m sec^{-1} km^{-1} are found in the prevailing wind, where negative gradients correspond to a decrease in wind velocity with height. This gradient has the result that at certain seasons the direction of the prevailing wind changes from east to west within the 80–100 km region. Thus, although

results at the mean height indicate that the prevailing wind blows towards west in autumn and spring, the height measurements show that below 90 km in autumn the wind remains easterly.

Lunar echo work.—Considerable modifications to the lunar echo equipment have been made during the period 1954 December to 1955 December, thus limiting the available observing time. The rapid fading of the echoes has been shown conclusively to be due to the libration of the Moon. The rate at which the Moon librates varies with its position in its orbit, and the echo fading rate (as characterized by the pulse-to-pulse autocorrelation coefficient) has been found to vary in a corresponding manner. The correlation between pulses is, however, only half that expected and indicates that correlation is being lost, possibly in the ionosphere or in the equipment. Hence it is not possible to ascertain with any high degree of accuracy the scattering law for the Moon from the autocorrelation function of the echoes. The results give best agreement, however, with the Lommel–Seeliger scattering law. Thus at the wave-length (2·5 metres) the moon appears to be " uniformly bright " across its disk.

The final amplifier of the transmitter has been rebuilt to give 10 kw peak output. A subsidiary experiment showed that 4 dB loss in echo power is caused by some of the transmitted output being radiated in frequencies outside the receiver bandwidth. This is caused by unwanted frequency modulation occurring in the transmitter. The aerial efficiency was measured using solar noise. When these two factors are taken into consideration, and the moon assumed to scatter according to the Lommel–Seeliger scattering law, and have an albedo of 0·1, the expected signal to noise ratio is $31{\cdot}8 \pm 1$ dB. The maximum mean signal to noise ratio which has been observed is $27{\cdot}2 \pm 2$ dB. Thus the assumed albedo is probably too high.

The long period fading, which has previously been shown to be due to the magneto-ionic effect in the ionosphere, causing a rotation of the plane of polarization, has been used to investigate the ionospheric electron content. The technique requires the equipment to be run alternately on two frequencies separated by 1·44 Mc/s. Since the angle of rotation depends both on the electron content and on the inverse of the square of the frequency in use, the signal to noise ratio curves for the two frequencies are displaced in time by an amount depending both on the total electron content and the rate at which it is changing.

The frequency separation employed has been dictated by the design of the transmitter, and is less than might be desired. Thus the separation of the signal to noise ratio curves for the two frequencies is small, and this limits considerably the accuracy at present obtainable. A full account of the above work has been prepared for publication (**22**).

Optical interferometer.—It is proposed to apply the principle of the post-detector correlation interferometer to measurements at optical wave-lengths. As a preliminary step it has been shown (**23**) in the laboratory that the photons in two coherent beams of light are correlated. In view of the success of this experiment a stellar interferometer, based on the new principle, is under construction.

International symposium.—A Symposium on Radio Astronomy, held under the auspices of the I.A.U., took place at Jodrell Bank on 1955 August 25, 26 and 27. The attendance had to be limited by invitation, and the Symposium was attended by nearly 120 delegates from 19 countries. An illustrated account

of the proceedings has been published in America (**24**). A full report is in course of publication by the I.A.U.

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University Observatory, Oxford

(*Director, Professor H. H. Plaskett, F.R.S.*)

Chromosphere.—With the 35·2 m telescope (**8**), Dr Treanor (**10**) has succeeded in photographing interference fringes of the chromospheric lines Hα and D_3. With the same instrument additional spectra were obtained for Mr R. O. Bishop's investigation of the latitude variation of the total intensities of these lines.

Red shifts of Fraunhofer lines.—From her interferometric determinations of the wave-lengths of solar and vacuum-arc lines in the region 5100–6700 A, Dr Adam (**1**) has found a unique linear relation between the red shift of the line (expressed in frequency units) and the logarithm of its total intensity. This relation is confirmed by the interferometric measures of Burns and his colleagues which extend over a wider range of line intensities and wave-lengths. During the observing season Dr Adam obtained interferometric spectra with the 19·8 m telescope of strong solar lines in order further to test this relationship. A puzzling systematic error in absolute wave-lengths has been traced (**2**) to slight irregularities in the surfaces of the interferometer plates, and an investigation has also been made of the correction for phase effect.

Line profiles.—Working at the centre of the heterochromatic fringe pattern, as suggested by Dr Adam, Dr W. R. Hindmarsh (**4**) has been able to show the

effect of hyperfine structure on the profiles of the solar Mn triplet at 6020 A. With the same method the Radcliffe Travelling Fellow, Dr T. D. Kinman, has made a careful survey of the violet wing of Hα in order to find the equivalent width of the deuterium line. The problem is complicated by the presence of a terrestrial water-vapour line in the predicted position of the deuterium component, but by making use of the Doppler shift due to equatorial rotation Dr Kinman (**5**) has been able to show that the abundance of deuterium is less than $0{\cdot}4 \times 10^{-5}$ that of hydrogen. Using the principle of detailed balancing expressions have been found for the absorption and emission coefficients of the continuum and line, and as a result a new numerical treatment of the integral equation of line formation (**7**) has been suggested.

Photospheric currents.—From 1120 determinations of equatorial solar rotation, based on the measures of 12 solar and atmospheric lines, Dr A. B. Hart (**3**) has found unambiguous evidence for the existence of photospheric currents with a spatial wave length of 26 000 km and a total amplitude of $0{\cdot}32$ km sec^{-1}. These currents, which persist for at least one hour, are on too large a scale and too long-lived to be directly connected with solar granulation. On the basis of a recent photospheric model (**6**), the currents have a kinetic energy comparable with the energy transported by radiation, and must be regarded as making a significant contribution to the energy transport in the photosphere.

Cepheid variables.—In his investigation of the galactic rotation of Cepheid variables Dr Stibbs (**9**) has made a new determination of the intrinsic colours of these stars. From these and the observed colours the interstellar absorption can be deduced, and with Baade's zero point of the period-luminosity law Dr Stibbs has found an Oort-constant $A = 20$ km sec^{-1} kpc^{-1} from the radial velocities measured by himself and Joy for the nearby Cepheids.

Staff.—After more than six years service Dr Gerald Merton has resigned his appointment as Departmental Demonstrator. Fortunately he continues his work at the Observatory in a voluntary capacity. Mr R. J. Bray has been appointed to the vacant Demonstratorship.

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University Observatory, St. Andrews

(*Director, Professor E. Finlay-Freundlich*)

Staff.—Mr F. D. Abbott has been appointed Night Assistant to the Observatory.

Mr J. W. Wilson, Mr P. Baylis and Mr E. G. Forbes joined the Observatory staff as Research Students.

Scientific Research

(*a*) With improved coronal interferometry equipment Dr A. H. Jarrett together with Dr H. von Klüber (Cambridge) prepared a renewed experiment for the total eclipse of the Sun in Ceylon on 1955 June 20. Monsoon clouds prevented any observations from the site at Hingurakgoda.

(*b*) Research on the red shift of the solar lines has been continued with Mr E. G. Forbes.

(*c*) Mr A. MacAulay's work concerning enhancement of the sensitivity of a photographic emulsion has continued.

(*d*) At the auroral station Dr Jarrett, together with Mr P. Baylis, commenced the construction of a radio echo equipment for auroral research during the forthcoming International Geophysical Year; Mr J. W. Wilson commenced auroral research with the f/0·7 spectrograph.

(*e*) Miss Middlehurst has continued the reduction of photoelectric data (3 colour magnitudes stars in NGC 1647 and 2244) obtained in Indiana.

(*f*) Dr Cisar has made with the 18-inch Schmidt–Cassegrain Telescope a photographic survey of the obscuring regions in Cygnus to be used in conjunction with a parallel survey of radio-emission being carried out at Jodrell Bank, and has begun a programme of observation of short-period variables in the neighbourhood of globular clusters. Preparatory work was made for the use of a Fabry–Perot Interferometer combined with the 18-inch telescope in observations of diffuse nebulae.

(*g*) Mr T. Slebarski's investigation on the accurate determination of the positions of faint stars with the 18-inch Schmidt–Cassegrain telescope is nearing completion.

(*h*) In the workshop, the floating systems for both mirrors of the 37-inch Schmidt–Cassegrain telescope are completed and the mirrors are mounted. The main drawings of the heavy mounting for the telescope are prepared and the orders for its construction are placed. The Iris diaphragm and the 8-inch guiding telescope are under construction.

Publications.—R. Kurth, " General theory of spherical self-gravitating star systems in a steady state ", *A.N.*, **282,** No. 3; R. Kurth, " Stellar orbits in Globular Clusters ", *A.N.*, **282,** No. 6; E. Finlay-Freundlich and R. Kurth, Über die Grundlagen, Ziele und Möglichkeiten einer mechanischen Theorie der Sternsysteme, *Die Naturwissenschaften*, **42,** Jahrgang, p. 167.

Norman Lockyer Observatory of the University of Exeter

(*Director, Mr D. L. Edwards*)

The colour-temperature programme has been continued, though observations are still far from complete. In the meantime work has continued on the technique of reduction, especially the use of Baker's function instead of photographic densities, corrections for variations in emulsion thickness, and the reduction of " gamma " values obtained by the use of colour filters in the sensitometer to true monochromatic values within the filter range.

The spectrum and colour-temperature of λ Cassiopeiae continue to show slight variations, and this star is still being regularly observed. An analysis is also being made of several series of visual magnitudes by other observers.

Spectrophotometric observations of the day and twilight skies have been continued and a research note embodying the results of two-colour photoelectric brightness and polarization measures of the zenith day sky has been published (D. R. Barber, *J. Atm. and Terr. Phys.*, **7**, 171). A novel twin-lens twin mirror sky camera, fitted with polarizing filters and designed to study the twilight Na emission pattern over a $120° \times 150°$ field, has been built in the observatory workshop, and initial tests are satisfactory. Photometric and field co-ordinate calibrations await completion before the instrument goes into routine use. Further work on the partly completed photoelectric photometer, for use with the Littrow spectrograph, has been deferred pending a reduction of plates obtained with the wide-field camera.

On July 28 the Observatory was opened to the public for visits both in the day time and at night. Special exhibits of instruments, photographs and research work were prepared, and visitors were shown the Sun and Moon through telescopes. It is intended to make this " open day " an annual event.

Dunsink Observatory

(*Director, Professor H. A. Brück*)

Staff.—Mr B. G. Tunmore, having done some research at the Cambridge Observatories, has joined the observatory as Scholar.

Equipment.—The new 28-inch Cassegrain reflector has been mounted in the dome on the roof of the main building. A twin-register pulse-counting photometer for use with this instrument has been constructed by Dr Smyth, and a photometer head has been completed in the workshop.

The solar Cassegrain telescope has been fitted with its new quartz optics giving it an effective focal length of 55 feet, and the spectrohelioscope has been rearranged as an independent unit, using for the telescope a 4-inch lens of 19-feet focal length. The two instruments are now fed by a redesigned twin coelostat with 16-inch and 8-inch mirrors, the secondaries of which have been mounted together on a polar axis.

Vacuum pumps have been acquired by the observatory so that aluminizing can now be done on the premises.

Solar work.—During the autumn Dr Thompson secured further ultra-violet solar spectrograms and has since been engaged on the laborious reduction of these and earlier plates.

ADH-Telescope.—The Harvard Corporation have transferred their part-ownership in the ADH-telescope to the Armagh and Dunsink Observatories. A further meeting of the new Administrative Council of the Boyden station which met at Uccle was attended by Professor Brück. Agreement was reached on continuing cooperation between the six institutions concerned for a two-year period in the first instance.

Dr Thompson spent four months at the Boyden station. Though he had first to overcome some major instrumental difficulties, he succeeded in obtaining some 60 plates of 6 open clusters in red, yellow and ultra-violet.

The Eichner plate photometer has been out of commission, but is now being put back into operation for the measurement of ADH-plates.

Meeting of the International Astronomical Union.—Members of the staff spent considerable time on preparations for the 9th General Assembly of the International Astronomical Union which was held in Dublin from August 29 to September 5. It was the best attended and most representative meeting which the Union has ever held, and, for the observatory, the most memorable event in its history. Nearly all of the 800 delegates and guests visited the observatory in the course of that week.

Dominion Observatory, Ottawa

(*Director, Dr C. S. Beals*)

Positional Astronomy.—Observations on a list of 3000 stars in the FK3 catalogue and the FK3 supplemental list, initiated in 1954, were continued during 1955. 6000 observations in right ascension and declination were made during the year.

The reductions of the photographic zenith telescope stars culminating near the zenith at Ottawa, Herstmonceux and Richmond, U.S.A., are partially completed, and results for the Herstmonceux stars were forwarded to the Astronomer Royal.

Plans for building a " Mirror Transit " as proposed by R. d'E. Atkinson of the Royal Observatory, Greenwich, continue. Drawings and specifications for many of the parts, the axis, mirror and objectives have been completed and orders have been placed.

The photographic zenith tube was in operation on 183 nights, 235 clock corrections and latitude determinations being made. The latitude of Ottawa reached a maximum of $38''\cdot9$ in 1954 October, a minimum of $38''\cdot4$ in 1955 July and seems to be reaching a maximum again about $38''\cdot7$ at the end of the year.

The primary standards in the Canadian time service consist of three crystal clocks; one being an Essen ring type, while the others use GT cut crystals. The ring crystal has consistently given the best performance, having a rate of $0^s\cdot060$ per day with a variation of a few parts in 10^9 while the rates of the others are stable to a few parts in 10^8. Two other crystal clocks, the rates of which are adjusted from time to time, were used to control time-signal machines and other observatory equipment requiring standard frequency.

Time signals were broadcast continuously as in previous years, the only change being a voice announcement of the time once each minute. The frequencies and power were 3330 kc., 0·3 kw; 7335 kc, 3 kw; 14670 kc, 0·3 kw. The announcement is put in automatically between 50^s and 60^s and comes from a machine controlled by one of the crystal clocks.

The original time-signal machines along with the Muirhead machines, all under crystal clock control, continue to transmit time signals over telephone lines to the transmitting station CHU, to the Canadian National and Canadian Pacific Railways, and to master clocks in government buildings.

Electronic methods in the comparison of clocks at the frequency level of the crystals themselves have been used to an increasing extent throughout the year.

Two cold cathode units were installed for the development of seconds and these will gradually replace the seconds contacts taken from a motor driven wheel.

Stellar Physics.—The Super-Schmidt cameras located at Meanook and Newbrook, Alberta, were used for routine meteor observations on all clear nights during dark of the moon periods. Approximately one thousand pairs of exposures were made during 250 hours of observation. Sixty per cent of these films have been searched yielding 35 pairs from which heights, velocities and decelerations can be computed. Approximately 1500 exposures were made with meteor spectrographs equipped with transmission gratings. Films searched have produced three spectra, one of which is a well resolved spectrum of a high velocity sporadic meteor. Work proceeded on a detailed study of the excellent Geminid fireball spectrum obtained in 1954 December.

The problem of computing the dimensions of the crater formed by a meteorite of given mass and velocity striking the Earth was studied and the consequences of various assumptions concerning the deformation of the ground near the explosive centre were worked out.

Research in the mathematical description of the radiation field continued.

The reduction of the chromospheric flash spectra obtained from an aircraft during the eclipse of the Sun of 1954 June 30, was carried forward. The centre-limb wave-length shifts of solar lines in the 10 000 A region was investigated using plates taken for this purpose with the 80-foot horizontal solar telescope and 20-foot grating spectrograph. Regular studies of the solar disk were begun using the H-alpha Lyot filter and associated time-lapse camera.

A search for lunar type or meteorite craters was made on aerial photographs of a limited portion of the Canadian Shield in Ontario and Southern Quebec. Two circular depressions 1·25 and 0·81 miles in diameter were found which may have a meteoritic origin. The two craters were filled with palaeozoic sediments, a circumstance which makes possible the establishment of minimum ages.

Geomagnetism.—Magnetic survey operations on the ground were restricted to areas in Nova Scotia, Quebec, Ontario and Alberta. Measurements of declination, inclination and intensity were made at fifty-seven points.

The three-component gyro-stabilized airborne magnetometer, developed by the Dominion Observatory, was employed on detailed magnetic mapping of the provinces of Manitoba, Saskatchewan and Alberta. Continuous registration of declination, horizontal intensity and vertical intensity was made on East–West flight lines 60 miles apart from the 49th to the 60th parallel of latitude, supplemented by three North–South lines. Total mileage flown was 30 000 representing 125 flying hours. The North Star aircraft used was supplied and manned by the R.C.A.F.

Magnetic Charts of Canada for the epoch 1955·0 showing declination, inclination, horizontal intensity, vertical intensity and total intensity were printed and made available for distribution.

The four magnetic observatories at Agincourt, Ontario, at Meanook, Alberta, and at Baker Lake and Resolute Bay, Northwest Territories, continued normal operations. The study of earth-current phenomena was commenced at Meanook Magnetic Observatory.

An analysis is under way of the characteristics of magnetic disturbance at the two Arctic observatories at Resolute Bay and Baker Lake whose geographical

coordinates are 74°·7 N and 265°·1 E; and 64°·3 N and 264°·0 E respectively. A number of interesting features of disturbance have been discovered; thus at Resolute Bay the daily disturbance variation can be represented very well by an expansion in amplitude of the quiet day effects with no change in form. One model which explains many statistical features of the measured transient changes is that of a relatively constant and simple tidal motion with greatly enhanced polar cap conductivity at the time of magnetic disturbance. The daily changes at Baker Lake are much more complex and it has proved impossible to determine the form of the real quiet day effects because of residual disturbance present on quiet days. The statistical results from Baker Lake are being applied to the determination of the morphology of the concentrated auroral zone currents in that neighbourhood. Sudden commencements and other storm phenomena are being studied at both stations in order to investigate whether their current sources are atmospheric in polar regions.

The data from Resolute Bay for the last five years have been used to determine the main daily, seasonal and annual drift of the North Magnetic Dip Pole.

Gravity.—Studies of gravity were actively pursued during the year with special emphasis placed on extending the primary base network within Canada and on improving the connections between the national base station at Ottawa and the world gravity network. One party using three gravimeters and aircraft transportation travelled about 30 000 miles to establish a system of forty-eight primary bases located at principal airports throughout southern Canada. The bases are, on the average, about 150 miles apart, and form a series of six closed nets extending from Vancouver, B.C., to Gander, Newfoundland. Accurate ties were made to previous gravimeter networks and to sites where pendulum measurements, both with the Mendenhall and Cambridge apparatus, have been made. The results of the three gravimeters are consistent to about 0·3 milligals and should therefore provide an accurate datum for adjustment and control of all regional gravity measurements throughout southern Canada.

To resolve some of the uncertainties in previous gravity connections between the fundamental gravity stations in Ottawa and Washington, D.C., a series of measurements between the two sites was also carried out during the year. Observations were made at some 25 stations to form a series of networks that permitted adjustment for closure. On the basis of instrumental calibrations carried out against Cambridge pendulum values, nine independent sets of measurements between these two important stations give differences in gravity that are consistent within one-tenth of a milligal.

A programme, using gravimeters, was also initiated during the year to strengthen the ties between the North American and European gravity networks. In cooperation with the Geophysical Observatory in Trieste, Italy, an accurate tie was successfully completed between Gander Airport, Newfoundland and Orly Field near Paris, France.

Studies of isostasy and the geological implications of the gravity results were actively continued during the year. With the objective of eventually producing an isostatic map of Canada, based upon the Airy hypothesis, the isostatic reduction work for about 300 gravity stations observed throughout the Cordilleran region of southern British Columbia was completed. A study of the preliminary gravity results for a large area of the Canadian Shield in southern and central Quebec has also been completed and papers giving these results are now ready for the press.

Seismology.—The Seismological Division normally maintains ten seismograph stations across Canada. During 1955 two stations were added to this network on an experimental basis with the aim of investigating local seismicity. These were at Fredericton, New Brunswick and Banff, Alberta.

The Western Section of the Division, with headquarters at Victoria, have continued studies of the seismicity of British Columbia, approximately 800 local earthquakes having been recorded.

During the summer the Division had two parties in the field. The first of these investigated rockbursts in coal mines at Fernie, British Columbia. The second party made seismic profiles across the Gulf of St. Lawrence and on Sable Island. It appears from the latter study that Sable Island is a true sand bar with no rock core.

The interest of the Division in the direction of faulting in large earthquakes has continued and a total of sixty-five earthquakes has now been analysed. The methods of graphical analysis employed by Canadian workers in this field have been carefully compared with those currently in use in Russia, Japan and Indonesia and it has been shown that though apparently diverse in approach the various methods are fundamentally identical. The implications of the results on theories of tectonics are being studied.

David Dunlap Observatory, University of Toronto
(*Director, Professor J. F. Heard*)

Radial velocities.—No new radial velocity programmes were undertaken during 1955. With the major programme of 1050 stars in the Yale Zone $+25^{\circ}$ to $+30^{\circ}$ completed, efforts have been made to complete other programmes which had been in abeyance for some years. Thus, observing and measuring have been nearly completed on several lists of stars in extensions of the Kapteyn areas and on a group of 60 stars which are believed by Heckmann to be members of the Alpha Persei cluster. Also some progress has been made on observations of a group of faint stars in the galactic polar cap and a selected group of faint OB stars.

An analysis has been made for the solar motion with reference to the 1050 late-type stars whose radial velocities have recently been determined here. The resulting values of the solar velocity are 13 km/sec for the giants and 16 km/sec for the dwarfs. Data are now available for a similar analysis using the tangential velocities of the same stars.

Heard and graduate students have completed spectrographic orbits for the eclipsing variables V451 Oph, V805 Aql and V548 Cyg and also for the hydrogen-poor star HD 30353. Miss Northcott has undertaken spectrographic orbits for the binaries HD 15138, 36484, 82780 and 154528.

Photometric.—Mrs Hogg has continued studies on variable stars in about ten globular clusters, particularly NGC 6273, 6712 and 6838.

Bakos has observed by the photoelectric photometer the magnitude and colour differences of the components of 117 late-type visual binaries for a study of the evolution of these systems. He has also discovered that the spectrographic binary HD 200391 is eclipsing and has found small light variations in the peculiar spectrographic binary HD 30353.

Oke obtained photographically several minima of the eclipsing variable Nova Herculis which were used by M. Walker at Mount Wilson and Palomar Observatories in establishing the accurate period.

Stellar luminosities.—Oke's continued study of luminosity classification of stars by means of a large number of luminosity criteria on calibrated microphotometer tracings yields mean errors of about $0^m{\cdot}2$ for G8- to K1-type stars. The method is being extended to include F-and G-type stars for both luminosity and spectral type. Spectra of 117 visual binaries have been obtained for luminosity studies by this method.

Computation.—MacRae has worked out methods of carrying out least-squares solutions of spectrographic binary orbits by means of FERUT, the electronic computing machine of the University of Toronto. All such orbit determinations here are now done in this way; a complete solution from preparation of the equations of condition to mean errors of the unknowns may be completed in a matter of minutes.

Staff.—Dr Donald A. MacRae was promoted to the rank of Professor and Dr Helen S. Hogg to the rank of Associate Professor. Dr Hogg was on leave of absence for part of the year to fill the position of Programme Director for Astronomy at the National Science Foundation in Washington; Dr Peter Wellmann of Hamburg Observatory has been Visiting Lecturer during her absence. Dr W. R. Hossack has resigned from the Observatory staff.

Publications.—Since the last report, *Pub. D.D.O.*, Vol. 2, Nos. 2 and 3, and *Comm. D.D.O.* No. 37 have been issued.

Dominion Astrophysical Observatory, Victoria

(*Dr R. M. Petrie, Dominion Astrophysicist*)

Staff.—Mr S. S. Girling, instrument maker, and Mr H. W. Dukeman, caretaker, retired in April after many years of valuable service to the Observatory. Mr D. H. Andrews joined the staff as astronomical assistant in May. The University of California awarded the degree of Ph.D. in astronomy to G. J. Odgers, and the University of British Columbia conferred the degree of D.Sc. (honoris causa) upon J. A. Pearce at its spring convocation. Miss A. B. Underhill is on leave for the academic year to join the staff of the Harvard College Observatory. Mr W. G. Milne is in residence at the University of California pursuing graduate studies in seismology.

The following held temporary appointments during the summer: R. O. Redman, Professor of Astronomy, Cambridge; S. G. Hacker, Professor of Mathematics, Washington State College; D. Robinson, University of Western Ontario; P. M. Cuttle, University of British Columbia; J. D. Francis, University of British Columbia; and A. K. Goodacre, University of British Columbia.

Spectroscopy.—The study of high-dispersion spectra of 31 Cygni, based on plates obtained during the 1951 eclipse, continues. K. O. Wright has determined the light-ratio of the components of this double star from line-intensity measures. The ratio varies from 1·35 at λ 3800 to 0·15 at λ 4500. The hydrogen and helium lines have been measured in the early-type component, which is found to be about B5. Wright has constructed curves of growth from line-intensities

of Fe I and Ti II for the chromospheric absorption and also for the normal K-type spectrum observed during the total eclipse. The chromospheric lines suggest a "turbulent velocity" of about 10 km/sec whereas the normal K spectrum gives a value about 5 km/sec. A. McKellar and R. M. Petrie have measured radial velocities of chromospheric lines and find departures from the variation which would be expected in a stable uniformly-rotating star. The measures suggest large-scale irregular motions in agreement with results already derived from studies of the K-line.

Infrared spectra of R Leonis (M8e) and R Cassiopeiae (M7e), obtained by A. McKellar, have resolved the wide absorption feature at λ 10 500 into a sequence of molecular bands degraded toward longer wave-lengths. At least six bands can be distinguished but their origin remains unknown.

Miss A. B. Underhill has completed a study of a number of O-type stars in galactic clusters. It is found that the total absorption in the ultra-violet hydrogen lines is correlated with absolute magnitude between O9 and B1 in agreement with previous tests. There does not appear to be a correlation between O5 and O8 and this is largely caused by the small range in absolute magnitude encountered among the O stars giving absorption spectra. It is suggested that high luminosity is accompanied by emission lines in the spectra between O5 and O8.

The broad interstellar feature at λ 4430 has been studied in the O-type spectra. The intensity of this unidentified feature is found to be correlated moderately well with distance and with colour excess.

The β-Cephei stars HD 199140 (BW Vulpeculae), β Cephei, and γ Pegasi, have been observed intensively by G. J. Odgers, every effort being made to obtain good time resolution. The following results have been obtained:

(*a*) HD 199140. Some 700 spectrograms have been obtained and measured. The period increase found previously was not maintained in 1953–55. The lines Hα, Hβ are weakened, presumably by emission, at the phase of maximum star. The radial velocity curves are discontinuous about the "stillstand" and there are noticeable variations from cycle to cycle in the radial velocity curves.

(*b*) β Cephei. Two complete cycles have been covered with high-dispersion. There does not appear to be any variation in the line profiles and the velocity curves are the same in both cycles.

(*c*) γ Pegasi. Three complete cycles were observed with medium dispersion, 14 A/mm at Hγ. The measures are not yet finished but it appears that the radial-velocity variation is small.

Observations of ϵ Aurigae have been made with high dispersion by K. O. Wright. Chromospheric absorption by Ti^+ and Sc^+ appeared at the beginning of the year and chromospheric lines of Fe, Ca, etc., began in July. All were stronger at the end of the year. The lines of the underlying F-type spectrum change in width in a non-regular manner but the total absorptions appear to remain constant.

The use of the absorption at Hγ to predict absolute magnitudes of B stars has been thoroughly tested by R. M. Petrie and B. N. Moyls. Spectroscopic absolute magnitudes for some 350 stars have been compared with (*a*) conventional mean parallaxes calculated from the proper motions, and (*b*) mean distances calculated from radial velocities, assuming galactic rotation. In addition, the

computed absolute magnitudes of 20 eclipsing systems are available for comparisons. All these tests confirm the system of absolute magnitudes given by the Victoria calibration.

The unidentified interstellar line at λ 3143, observed by Spitzer and Field in the spectrum of ζ Persei, has been identified by A. McKellar and E. H. Richardson as the $Q_2(1)+QR_{12}(1)$ line of the $^2\Sigma$, $^2\pi$ transition of CH molecule.

R. O. Redman has measured line intensities in spectra of a number of normal- and high-velocity K-type stars. No significant spectroscopic differences between the two groups have been found so far.

Spectra of comets 1955e, 1955f, and 1955g have been obtained. The spectra of the three objects are much alike and are dominated in the ordinary region by emission bands arising in CN, C_2 and C_3.

Stellar motions.—During the year some 1400 spectrograms have been measured for radial velocity. The spectra are largely of β Cephei stars, B-type stars, members of galactic clusters, and spectroscopic binaries.

A study of the Taurus cluster has been completed by J. A. Pearce. The convergent point is found to be $A=91^\circ\cdot8\pm0^\circ\cdot65$, $D=+9^\circ\cdot1\pm0^\circ\cdot25$ (1950 coordinates). The space motion has been found from radial velocities of 97 members of spectral types A–K using the revised wave-length system. The value is $+43\cdot0\pm0\cdot22$ km/sec. The Taurus cluster may be considered to be sufficiently well known for the stars to be used as standards for absolute magnitude and radial velocity.

J. A. Pearce has completed the radial velocity measures of an extensive programme of members of the Pleiades cluster, the velocities of 91 members being determined. These data together with previous determinations and proper motions will serve for a new determination of the convergent and space motion.

Progress has been made on the programme of faint B stars for which the spectrographic observations are essentially complete. Radial velocity measures of some 200 stars have been completed by R. M. Petrie. Several hundred microphotometer tracings of spectra in the region $\lambda\lambda$ 3900–5000 have been made by E. K. Lee. Spectral line intensities have been measured on records of 60 spectrograms by Miss J. K. McDonald who is undertaking an extensive programme of intensity measures of the main lines observable with moderate dispersion in the photographic region of B-type spectra. The measures include interstellar features and $H\gamma$, the latter to supply spectroscopic absolute magnitudes. Photoelectric magnitudes and colours are being measured by P. E. Argyle for the stars not included in the programme of Stebbins and Huffer and Whitford.

A determination of Oort's constant, A, has been made from 74 B stars by R. M. Petrie using stellar and interstellar velocities. The stars chosen have been measured for spectroscopic absolute magnitude and colour excess, and give a distance range of 6·7–10·1 kpc. from the galactic centre. A is calculated using, first, the method proposed by Weaver, and second, the usual double-wave approximation. The two methods give essentially the same numbers and the mean value, from this sample, is $A=17\cdot8\pm1\cdot1$ km/sec/kpc.

Spectroscopic binaries.—Orbital elements and spectroscopic Δm have been derived for the two-spectra binaries HD 110854 (A. McKellar and E. H. Richardson) and HD 190967 (R. M. Petrie). The latter is of special interest since it is an eclipsing binary having high-temperature, and massive, components.

The spectroscopic dimensions do not agree with those deduced from Ashbrook's light-curve.

Radial velocities have been measured for the star HD 131511 by K. O. Wright and P. M. Cuttle. The velocities cannot be explained by binary motion only, and it is suspected that a third body is present.

Series of observations for orbital studies have been made of the following binaries: ζ Aurigae, 55 Ursae Majoris, HD 157978–9, HD 175544, 31 Cygni, S Equulei, HD 208947, AR Cassiopeiae.

Photoelectric photometry.—The scanning device for work on visual double-stars has been improved by the addition of an image rotator and a motor-driven image-shifter. Five-colour measures have been made of about 100 stars on the B star programme and the North Galactic Pole programme. Measures have been made of a number of spectroscopic binaries. The colour and magnitude measures have been made entirely by P. E. Argyle.

Magnitudes and colours have been measured by P. E. Argyle for 45 stars in the cluster h Persei. This is part of a programme to determine whether the absolute magnitude effect on the ultra-violet hydrogen lines can be determined by the rapid and convenient methods of photoelectric colour observations.

Theoretical studies.—G. J. Odgers has continued theoretical investigations of certain problems. The following results have been obtained:

(*a*) An interpretation of the behaviour of the β Cephei star HD 199140 has been made in terms of a shock wave treatment of a sub-photospheric disturbance. The outer atmosphere is thrown off the star and falls back under gravity. The appearance and behaviour of the double-line phase may be explained and an extension of the treatment is expected to throw some light on Cepheid variation generally.

(*b*) The integral equation arising in the theory of the curve of growth has been solved exactly. If the analytical form of the curve is known we can then infer the distribution of the important physical parameters with depth.

(*c*) The equation governing the equilibrium of a rotating cylindrical polytrope is derived and the properties of the solution found. The impossibility of fission may be proved and may be inferred also for rotating spherical polytropes.

(*d*) Other work includes an investigation of the Russell–Vogt theorem in stellar structure, and a study of the mathematical theory of Cepheid variation.

Miss J. K. McDonald has prepared tables of some Kourganoff integral functions as used in the theory of stellar atmosphere models. She has also prepared tables of the Planck Function $B\nu(T)$ over wide ranges of frequency and temperature. The tables were computed with the electronic calculator of the University of Toronto.

Seismology.—The four stations of the Western Canadian network were operated continuously and a fifth station was installed at Banff, Alberta, in July. Equipment at Victoria was augumented with the installation of long-period galvanometers and recorders so that good records are obtained of distant earthquakes.

An intensive study was carried out on the stress-strata project in the Coleman–Fernie area during the summer. Equipment for the radio transmission of disturbances to a centrally located recorder was installed and found to work well.

Up to the first of December, 173 local earthquakes were recorded.

Instrumentation.—Two new cameras, incorporating some mechanical improvements, were constructed in the shop and are now in use in the stellar spectrograph. The addition of a grating with high efficiency in the first order in the ultra-violet has made it possible to obtain stellar spectra with moderate dispersion (15 A/mm) to the limit of atmospheric transmission.

The photoelectric exposure meter has been completed and installed in the spectrograph. This instrument has shown excellent performance and has increased efficiency in the obtaining of stellar spectrograms.

Publications.—During the year, the following papers were sent to the printer :

Publications of the Dominion Astrophysical Observatory:

Vol. X, No. 4. " Tables of the Functions M_0^τ , N_0^τ , ϕ_2^τ , ϕ_3^τ useful in Equation of Transfer Problems " by J. K. McDonald.

Vol. X, No. 5. " Tables of the Planck Radiation Function $B_\nu(T)$ " by J. K. McDonald.

Vol. X, No. 6. " A Spectrographic Study of Eta Aquilae and Delta Cephei " by T. S. Jacobsen.

Vol. X, No. 7. " On the Use of the Hydrogen Lines as Absolute Magnitude Criteria in the O Stars " by Anne B. Underhill.

Vol. X, No. 8. " An Investigation of the Strength of the Interstellar Absorption Feature at λ 4430 in the Spectra of O Stars " by Anne B. Underhill.

Vol. X, No. 9. " A Further Study of the β Cephei Star HD 199140 (BW Vulpeculae) " by G. J. Odgers.

Vol. X, No. 10. " Spectrographic Orbital Elements for HD 110854 " by E. H. Richardson and A. McKellar.

Vol. X, No. 11. " The Orbits and Spectra of HD 190967 (V448 Cygni) " by R. M. Petrie.

Vol. X, No. 12. " On the Composite Spectrum of HD 50820 " by Anne B. Underhill.

Title Page, Table of Contents, List of Plates, and Index for Volume IX.

Contributions of the Dominion Astrophysical Observatory:

No. 44. " The λ 10500 Absorption in the Spectra of Late M-type Stars " by Andrew McKellar.

No. 45. " The Light-Ratio and the Spectrum of the Secondary Component of the Eclipsing Binary 31 Cygni " by K. O. Wright and E. K. Lee.

No. 46. " Pre-Eclipse Observations of ϵ Aurigae " by K. O. Wright.

Union Observatory, Johannesburg

(*Director, Dr W. H. van den Bos, Union Astronomer*)

The 26½-inch refractor has been used by Dr Finsen on 214 nights with the interferometer for the measurement of known double stars and a survey for new ones, and by Mr Churms and Dr van den Bos on 51 nights with the micrometer.

Dr Finsen prepared multiple reproductions, in colour as well as in black and white, from the roughly 24 000 exposures on colour film of the planet Mars which he obtained in 1954.

With the 9-inch refractor 94 and with the 6-inch photovisual refractor 56 occultations have been observed by Messrs Bruwer and Churms and amateur astronomers, members of the Transvaal branch of the Astronomical Society of South Africa, principally Messrs J. H. Botham and I. R. H. Brickett, who also made observations of planets, variable stars, etc., on 84 nights with the 9-inch refractor and rendered valuable assistance on visiting evenings and in other ways.

With the Franklin–Adams telescope at the Observatory's Annexe at Hartbeespoort Messrs Bruwer and Churms took 199 plates for minor planets and 18 for comets; 2 occultations were observed.

Counts of sunspots were made on 265 days.

The Time Service is operated by Messrs Hers and Seligmann. Mr Hers left for England on March 4 to receive a set of quartz crystal oscillators made by the British Post Office Radio Branch and returned on March 31.

Dr van den Bos left for Europe on April 23, attended the I.A.U.Assembly at Dublin, visited the observatories at Stockholm, Copenhagen and Leiden and returned on October 31.

During the year 1218 visitors were admitted on 38 nights.

Dr Muller was the Leiden Observer throughout the year.

Union Observatory Circular No. 114 was printed and distributed.

Papers by members of the staff published in other periodicals were :

W. S. Finsen : " Cinematography of Mars " (*Research Film*, vol. 2, p. 20); " New Double Stars " (*The Observatory*, **75**, 133, 1955); " A critical evaluation of Sinton's achromatic interferometer " (*J.O.*, **38**, 217, 1955); and " The orbit of ϵ Ceti " (*M.N.A.S.S.A.*, **14**, 84, 1955).

J. Hers and P. C. Seligmann : " The Union Observatory time and frequency transmissions " (*S.A. Journal of Science*, **51**, 195).

P. C. Seligmann : " Quartz Clocks " (*M.N.A.S.S.A.*, **14**, 10, 1955).

W. H. van den Bos : " Note on Dr Wilson's specific procedure for the measurement of close double stars with the filar micrometer (*A.J.*, **60**, 363, 1955).

Radcliffe Observatory, Pretoria

(*Director, Dr A. D. Thackeray, Radcliffe Observer*)

Equipment.—An aluminizing tank to hold the 74-inch mirror, constructed in the workshops of the Vanderbijl Engineering Co., was installed in the Observatory laboratory in 1955 October. Residual equipment is expected to be received during 1956 in time to aluminize the 74-inch mirror during the summer 1956–57.

Progress has been reported by Cox, Hargreaves & Thomson Ltd. on the construction of the Coudé Spectrograph and it is hoped that the completed instrument will be received and installed during 1956.

Observations. (*a*) *Radial velocities.*—Observations and reductions of 100 Bo–B2 stars with $m_0 - M \geqslant 11$ are essentially complete. This programme will be extended during 1956 with some additional, equally distant, B stars selected from various sources. Consultation of Wilson's General Catalogue shows that

this programme will yield a richer concentration of known velocities of distant B stars in galactic longitudes 240°–300° than is at present available in northern sectors of the Milky Way.

Observations of some brighter B stars with known velocities are being continued, partly in co-operation with the Dominion Astrophysical Observatory, Victoria.

Velocities of 26 stars belonging to the Large Magellanic Cloud have been measured and analysed. The results indicate a rotation of the Cloud in a sense which agrees with the radio results of the Australian workers; the fact that the optical results give a rotational velocity more than twice that indicated by the radio results is apparently due to the complexity of the radio profiles which refer to the whole depth of the Clouds. A parallel investigation of the Small Cloud is in progress.

Spectra of 6 bright Harvard Cepheids in the Magellanic Clouds have been obtained.

At the suggestion of Professor Irwin and Dr Wesselink, spectra of 26 stars in NGG 6087 and 43 stars in M25 have been obtained for velocities and spectral types. These clusters are of special interest in that each contain a classical Cepheid variable.

Of a number of variable velocity stars being investigated, the eclipsing variables BL Tel and AR Pav have received special attention.

In a programme on velocities of southern Me variables, one or more spectra of about half those stars south of Dec. −30° with $m_{max} < 10$ have now been obtained.

(*b*) *Stellar Spectroscopy.*—A spectroscopic study of S Doradus during the period 1951–55 has been completed and communicated to the Society. Variations in spectrum and light are being followed; an interesting feature has been the appearance of diffuse [Fe II] emission during a faint phase.

A further paper on the spectral variations of the slow nova RR Tel has been submitted to the Society. The presence of [Fe IV] emission has been established. The progressive changes towards higher ionization closely parallels the behaviour of RR Pic and RT Ser and approximate relative rates of development of these three objects and of Eta Car have been calculated; these rates suggest that Eta Car may have brightened from a pre-nova stage not very long before Lacaille's observation in 1757.

In a search for southern β Cephei variables, B. Pagel has found velocity variations in β Cru, τ^1 Lup and α Lup in periods of approximately 0·160, 0·177 and 0·260 days respectively. Light variations have been established at the Royal Observatory, Cape, for β Cru and τ^1 Lup. α Lup failed to show light variation during one night's test at the Leiden southern station and this star may not therefore be a true β Cephei object.

Classification of the brightest stars in the Magellanic Clouds is in progress. In conjunction with photoelectric observations it is hoped to extend this work to stars fainter than 12·0.

Spectra of ζ Aur during eclipse were obtained for spectral classification of the K giant freed from the B type component.

(*c*) *Direct photography.*—Detailed examination of the variables in the Sculptor system discovered on plates taken in 1949–1951 has been resumed by C. Jackson.

Plates of 47 Tucanae in two colours, with diaphragmed primary, have been obtained for the purpose of a colour-magnitude array.

Various fields in the Magellanic Clouds have been photographed in conjunction with the spectroscopic programme.

(*d*) *Photoelectric photometry.*—Three colour photometry of bright members of both Magellanic Clouds is in progress. 50 early B type stars in the Cape Zone Faint Catalogue in the region of 17^h R.A. have been observed in three colours with a view to selecting the most distant for radial velocity observations. A parallel programme at the Royal Observatory, Cape, through the kind cooperation of Dr R. H. Stoy, will provide a further selection of distant B stars in the region of 8^h R.A. and in S.A. 172, 193, 194.

Standard sequences have been obtained in collaboration with Dr H. C. Arp in the region of the globular clusters 47 Tuc and NGC 1466.

Visiting astronomers.—Work by visiting astronomers has included the following:

(1) About 1350 3-colour photoelectric observations of Cepheids by Professor J. B. Irwin (University of Indiana); (2) photographic and photoelectric work down to 18th and 19th mag in certain areas of the Small Magellanic Cloud, particularly in the region of NGC 419 for the purpose of studying stellar populations by Dr H. C. Arp (University of Indiana and Mt Wilson and Palomar Observatories); and (3) radial velocities of high-luminosity B stars and photography of ω Cen (Leiden Observatory).

Allocation of every third night to the Royal Observatory, Cape, has continued in accordance with the co-operative scheme; for this work see the Report by H.M. Astronomer at the Cape.

General.—The season was the poorest one for several years, particularly in the delayed onset of stable winter conditions. The telescope was used for 277 nights and the total number of night hours used failed by a small margin to exceed 2300.

A note on the identification of interstellar CH 3143·22 was published in *Obs.* **75,** 182, 1955.

The Observer attended the General Assembly of the International Astronomical Union in Dublin where he presented results of the spectroscopic work on stars in the Large Magellanic Cloud at one of the Symposia and presided at the meeting of the Radial Velocity Commission.

Staff and visitors.—During most of the year one of the three permanent resident astronomical staff was absent on leave. C. Jackson has joined the staff as Research Assistant on a part-time basis. B. Pagel, Radcliffe Student, worked at the Observatory from February to June.

The following visitors have used the telescope during the year: from the Cape Observatory, A. J. W. Cousins, J. Driver, D. S. Evans, J. v. B. Lourens, A. Menzies, T. W. Russo, L. Tillbury, J. B. G. Turner; from Indiana University H. C. Arp and J. B. Irwin; from Leiden Observatory, A. Muller.

In addition the following have visited the Observatory: E. G. Burton, H. Haffner, J. Sidgwick, G. I. Thompson, A. Velghe, P. Wellmann and Mrs H. E. Wood.

Nizamiah Observatory, Hyderabad

(*Director, Dr Akbar Ali*)

Astrographic equatorial.—The 8-inch photovisual object glass of the astrographic telescope arrived here after re-figuring in 1955 January and is being kept in the stores, pending repairs to the domes of the telescope houses.

47 plates were taken mostly in the ecliptic regions for minor planet and cometary work with the 5-inch Astrocamera.

The coordination of the results of the survey of photographic doubles in the Hyderabad astrographic zones $-17°$ to $-23°$ has been completed and the copy for press of the catalogue is being prepared.

Comparison of the rectangular measures of stars appearing in the Oxford astrographic catalogues, zones $+32°$ and $+33°$ with those appearing in the Potsdam Himmelskarte catalogues (difference of epochs over 37 years) was taken on hand for deriving proper motions. So far, 14 common regions containing 2566 stars have been compared by S. Aravamudan and 282 proper motions were found.

Grubb equatorial.—Micrometrical measurements of the distances and position angles of double stars and a few physical observations of comets Schwassmann (1925 II) and Perrine—MRKOS (1955 i) were made.

Flare stars were also kept under observation but no flare was noticed.

23 occultations of stars by the moon were observed and reduced. The results will be communicated to the Nautical Almanac Office for inclusion in the annual discussion.

The sky was exceptionally cloudy for telescopic work during the year.

Spectrohelioscope.—The Sun's disk was observed in Hα on 146 days for about $1^h\,20^m$ on average per day. 10 flares, all below importance 3, were observed. Dark filaments with 14 shifts towards violet and 17 towards red were also observed. 14 prominences with 5 shifts towards violet and 9 towards red were noted. The data of the solar observations have been sent for incorporation in the Quarterly Bulletin of Solar Activity (Zürich).

Spectrohelioscopic observations were taken by Habeeb Alvi for 112 hours and by G. Mohiuddin for 85 hours during the year.

Publication.—A paper on the calculation of heliographic coordinates was sent for publication in the *Journal des Observateurs*.

Equipment.—The driving mechanism of the 15-inch Grubb is practically worn out after a continued use for about 50 years. There is no slow motion in R.A. Designs for an electric driving clock with slow motion are complete and orders for the component parts have already been placed.

In connection with the proposals for modernizing the equipment submitted to the Osmania University last year, a meeting of the University Grants Commission of the Government of India was held at the Observatory on 1955 December 20.

The University has sanctioned the necessary funds for covering the domes of the two telescope houses with masonite. It is expected that the work will be completed early in 1956.

Library.—The University Grants Commission have kindly placed liberal funds at our disposal for expanding the library. The Observatory will be able to fill up the lacunae in its periodicals section.

Miscellaneous.—Dr Aneesur Rehman was appointed to the post of Astronomer in the Observatory. He has, however, taken long leave for prosecuting his researches in molecular structure as Senior Research Fellow of the National Institute of Sciences of India.

Lectures in practical astronomy were delivered to the graduate classes of the Osmania University.

The other routine work such as preparing the official calendar, seismological work and compilation of rainfall statistics of the Hyderabad State continued as usual.

Kodaikanal Observatory, Kodaikanal

(*Director, Dr A. K. Das*)

General.—On May 12 news was received of the death of Dr Thomas Royds, who was Assistant Director of Kodaikanal Observatory from 1911 to 1922 and Director from 1922 to 1937; as a mark of respect to his memory the observatory was closed for the rest of the day.

Dr A. K. Das attended the 9th General Assembly of the International Astronomical Union held at Dublin from August 29 to September 5 and the symposium on Radio Astronomy organized by the International Astronomical Union at Manchester before the Dublin meeting. He spent three weeks in the U.S.S.R. visiting important astronomical centres as a guest of the U.S.S.R. Academy of Sciences, and attended the Conference on Physics of the Sun, Stars and Nebulae at the Crimean Astrophysical Observatory between September 19–22.

Three Russian scientists visited this observatory in 1955 January. Other foreign visitors during the year were five Japanese astronomers and a French astronomer from the Paris-Meudon Observatories who came to this observatory after their eclipse expedition to Ceylon.

Final orders were placed with Messrs Sir Howard Grubb, Parsons & Company, Newcastle-upon-Tyne for the projected large Solar Telescope. Steps were taken for placing final orders with Messrs Optique et Précision de Levallois, Paris for the principal optical components of a Lyot Monochromatic Heliograph.

The fourth meeting of the Standing Advisory Board for Astronomy and Astrophysics in India was held at New Delhi in 1955 February, when details concerning the equipment and the objectives of the proposed Central Stellar Observatory were discussed.

Eclipse observations.—An expedition from this observatory consisting of 7 members was organized for making optical, geomagnetic, ionospheric and radio-astronomical observations during the total solar eclipse of 1955 June 20. A camp was set up at Hingurakgoda in Ceylon near the central line of totality. An intensive programme of solar, ionospheric and geomagnetic observations was also carried out at Kodaikanal for several days including the day of the eclipse. Unfortunately, owing to cloudy weather, optical observations were

impossible at Hingurakgoda, but the geomagnetic, ionospheric and radio astronomical observations were successfully made.

During the partial solar eclipse of 1955 December 14 frequent geomagnetic and ionospheric observations were made at Kodaikanal and a close watch was also kept on the variations of solar activity on that day.

Scientific cooperation.—Exchange of spectroheliograms with foreign observatories was continued. 263 K-disk spectroheliograms for the period 1954 October–1955 September were sent to the Cambridge University Observatories. For the period 1954 January–1955 June, 84 H-alpha disc and 77 K-disc spectroheliograms were received from Meudon Observatory, France and 119 H-alpha disc and 133 K-Prominence spectroheliograms from Mt Wilson Observatory, U.S.A.

In connection with the publication of daily maps of the Sun under international cooperation sponsored by the Fraunhofer Institut, Germany, copies of daily spectroheliograms (disk in H-alpha and K, and limb in K) on 35 mm film were supplied in fortnightly batches to Professor Dr K. O. Kiepenheuer with effect from the 1955 April 1.

Three photoheliograms together with the relevant zero plates for certain specified dates in 1954–55 were supplied to the Astronomer Royal, Royal Greenwich Observatory.

Quarterly statements relating to solar flares were sent as in previous years to the Meudon Observatory, France, and to the Royal Greenwich Observatory, England.

Periodical lists of solar flares and relative sunspot numbers, information relating to central meridian passage of prominent sunspots and forecasts of expected magnetic and ionospheric disturbances were supplied to a number of interested institutions in India.

The practice of supplying to the Chief, Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, U.S.A., the monthly median values of F2 layer critical frequency and the maximum usable frequency factor for 3000 km transmission was continued. Monthly median values of all ionospheric parameters were supplied to him and to the Director, Radio Research Station, Slough, England, in quarterly statements. The practice of broadcasting URSIGRAMMES relating to solar and geomagnetic activity was continued.

Routine observations.—Photoheliograms were made on 289 days and visual observations of the Sun were also possible on 289 days as compared to 299 and 289 days respectively in 1954. H-alpha disk, K-disk and K prominence spectroheliograms were taken on 275, 264, 258 days as compared to 278, 264 and 251 days respectively in the previous year. Observations with the spectrohelioscope were made on 281 days.

The average definition of the Sun's image on a scale in which 1 is the worst and 5 the best was 3·1—same as in the last year. There were 40 days on which the definition was 4 or better.

Sunspot activity.—Sunspot activity was on the increase during the year, the increase being pronounced during the second half. There were only 56 spot-free days out of a total of 289 days of observations compared to 243 spot-free days in 1954. The yearly mean latitude of all the observed spot groups in the northern and southern hemispheres was 25°·1 and 25°·5 respectively as against

24°·8 and 20°·2 for the previous year. Details of sunspot observations are given in the following table :

Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of new spot-groups	N	3	7	0	4	3	1	5	8	6	11	14	6	68
	S	4	2	1	1	1	2	3	3	6	6	7	7	43
Total		7	9	1	5	4	3	8	11	12	17	21	13	111
Mean daily no. of spot-groups		1·52	1·64	0·35	0·79	1·50	1·10	1·58	2·13	2·78	2·60	5·10	3·90	2·08
Kodaikanal daily relative sun-spot number*		22·0	21·6	4·7	11·5	23·2	22·1	21·9	37·3	35·3	38·2	78·8	60·1	31·4

* The relative sunspot numbers published in the previous Annual Reports were based on the visual observation of a solar image of 8-in. diameter projected on a screen by a refractor of 2¾-in. aperture. From 1955 January the relative sunspot numbers are those computed from photo-heliograms on a scale of 8 inches to the solar diameter obtained with a 6-in. refractor. The constant K in the formula for relative sunspot numbers is taken as 1.

Solar flares.—5 solar flares were observed during the year, all of intensity 1.

Radio astronomy.—Recording of solar noise at 100 Mc/s was temporarily discontinued because of instrumental defects. An equipment for recording radio-radiations from the Sun at 200 Mc/s was built for observations during the 1955 June 20 eclipse.

Geomagnetic observations.—Continuous photographic recording of *H*, *Z*, and *D* with Watson and La Cour Magnetographs and visible recording of the Horizontal Force with an Askania Field Balance were continued. Measurements of *H* and *D* were made weekly with QHM Nos. 254, 255 and 256. Vertical Force was determined weekly with a BMZ. Absolute measurements of *H* and *D* with the Kew Magnetometer were restricted to once a month and of vertical force with an earth inductor to once a week.

During the year 12 magnetic storms with ranges in *H* between 110 γ and 285 γ were recorded. Of these 4 were of the sudden commencement type.

Ionospheric observations.—Vertical incidence h'f ionospheric observations, which were previously confined to daylight hours, were extended to twenty-four hours from 1955 September 1.

Commencing with the data for 1955 September, hourly values of all ionospheric parameters together with magnetic storm, sunspot number and solar flare data were supplied to the Secretary, Radio Research Committee, Council of Scientific and Industrial Research, New Delhi for publication in the Radio Research Committee bulletins.

Cosmic ray.—Recording of cosmic ray intensity with the Kolhörster apparatus had to be discontinued due to shortage of staff.

Seismology.—The Milne-Shaw Seismograph (E–W component) recorded 109 earthquakes.

Meteorology.—Meteorological observations with all the visual and self-recording instruments were carried out as usual.

Library.—66 books and 1669 periodicals were added to the library.

Research work.—Under the Research Training Scheme sponsored by the Government of India, Ministry of Education, one Senior and two Junior Research Scholars were working in this observatory.

Astrophysics.—The following problems were under investigation :—

1. A study of the red-shift of solar spectrum lines and its relation to the Theory of Relativity.

2. The distribution of calcium flocculi on the Sun's disk.

3. Measurements of intensities of selected Fraunhofer lines in the solar spectrum, especially their variation from the centre of the disk to the extreme limb.

4. Variation of continuous absorption in the near ultra-violet solar spectrum.

Geophysics.—The following problems in geophysics were investigated during the year :—

1. Study of ionospheric and geomagnetic effects during the total eclipse of the Sun of 1955 June 20 at Hingurakgoda and Kodaikanal.

2. Study of magnetic disturbance field at Kodaikanal.

3. Study of vertical movements in the F-region of the ionosphere over Kodaikanal.

Publications.—The following papers were either published or prepared for publication :—

(1) " The magnetic disturbance field at Kodaikanal ", *Indian J. of Met. and Geophys.*
(2) " Solar tides in the F2 region over Kodaikanal ", *Indian J. of Met. and Geophys.*
(3) " Effect of the solar eclipse of 1955 June 20 on the lower ionospheric layers ", Kodaikanal Observatory Bulletin.
(4) " Ionospheric F2 layer behaviour during the eclipse of 1955 June 20 ", Kodaikanal Observatory Bulletin.
(5) " A study of the geomagnetic variations during the total solar eclipse of 1955 June 20 ", Kodaikanal Observatory Bulletin.
(6) " Day-to-day variation of cosmic ray intensity at Kodaikanal ", to be published by the National Institute of Sciences of India.
(7) " Quarterly synopses of results of solar, magnetic and ionospheric observations ", *Indian J. of Met. and Geophys.*
(8) Annual Report of the Kodaikanal Observatory for the year 1954.
(9) Reports to the Society on (i) the work of the Kodaikanal Observatory and (ii) the prominence activity for the year 1954, for publication in *M.N.*

Uttar Pradesh State Observatory, Naini Tal

(*Chief Astronomer, Dr M. K. Vainu Bappu*)

Buildings and equipment.—The most important single development during the year pertained to the decision by Government that the Observatory will be finally located on Manora Peak, Naini Tal, at a height of 6400 feet above sea level. About one hundred and twenty acres of reserve forest land have been transferred to the observatory by the Forest Department. The plans for the various buildings have been drawn up by the State Architect and the actual construction will be started by the Public Works Department before the end of March 1956.

Precision testing and calibration equipment purchased during the year have increased a great deal the resources of the electronics laboratory. Numerous small items of instrumentation dealing with photography and a general workshop have also been acquired.

Two more quartz master clocks have been ordered from Messrs Rohde and Schwarz of Munich. These, with the two other quartz clocks obtained from the same manufacturers, and now in the possession of the observatory, will comprise the nucleus of the time section of the observatory. A Riefler Cylinder

chronograph type UC2, together with a Cambridge 3-pen chronograph form the connecting links between star and the clocks.

More than eight hundred books on mathematics, physics and astronomy have been purchased for the library. Many observatories the world over have very generously sent in as complete sets as possible of all their publications. These have greatly aided the initiation and growth of a good library which will play a vital role in the future contributions made from this Observatory.

An order has been placed with Messrs Cox, Hargreaves and Thomson for a 22-inch mirror in tube, along with an 18-inch Baker corrector. These optics will temporarily be used on the 10-inch Cooke mounting now at the Observatory, until a separate mounting can be made for the 22-inch. Messrs Cox, Hargreaves and Thomson are also to supply us the optical parts for a ten-inch coelostat and horizontal telescope.

Research.—A spectrographic study of the Wolf–Rayet eclipsing binary HD 214419 is now nearly complete. Blue and red plates taken with the cassegrain spectrograph of the Mount Wilson sixty-inch reflector have been measured for radial velocities and also used for spectrophotometry. Radial velocity curves have been obtained from the different emission lines in order to derive the systematic velocities given by each. Monochromatic light curves in the light of the different emission lines follow the anomalous variation of He II 4686 found by Hiltner in this star.

Emission-line intensities have also been measured on Mount Wilson 60-inch spectra at different phases of the Wolf–Rayet binaries HD 193576 and HD 193928. Work is now in progress on two other binary systems, HD 211853 and HD 186943.

In collaboration with Dr Olin Wilson a study of the nucleus of Campbell's hydrogen envelope star at high dispersion has been completed. The paper containing a newer list of wave-lengths and identifications is now ready for publication.

Solar eclipse.—Preparations were made for the measurements of coronal isophotes in the visible region as well as for a study by photographic methods of the polarization of the outer corona at the total solar eclipse of 1955 June 20. A three-man expedition sent from this observatory was stationed at Hingurakgoda, Ceylon. Clouds prevented any successful exposures being made during totality.

Staff.—Mr Subhash Chandra was appointed research assistant with effect from 1955 September 15.

Visitors.—Dr Harlan J. Smith of Yale University Observatory visited the Observatory during the last week of December.

Commonwealth Observatory, Mount Stromlo

(*Director, Professor R. v. d. R. Woolley, Commonwealth Astronomer*)

The outstanding item to be mentioned in this report is the resignation of Professor R. v. d. R. Woolley, F.R.S., from the post of Commonwealth Astronomer to take up the office of Astronomer Royal. Professor Woolley after sixteen years at Mount Stromlo vacated the position of Commonwealth Astro-

nomer on 1955 December 7. By this date most of the large scale construction programme initiated by him at Mount Stromlo had been completed.

Telescope installation.—During 1955 three major telescopes have been brought to the testing stage. These instruments are (*a*) a 74-inch reflector (Sir Howard Grubb Parsons) which was formally opened by the Governor-General of the Commonwealth, His Excellency Sir William Slim, on 1955 November 8, (*b*) a 50-inch reflector (the former Great Melbourne Telescope of 48 inches aperture) which had been extensively reconditioned and modified at Mount Stromlo, and (*c*) the 26-inch Yale-Columbia refractor which was erected in a dome provided by the Commonwealth Government and modernized in the Observatory shops. A fourth telescope—a photographic zenith tube installation—has been delivered in Canberra but not erected. In addition to these items a dome and building for a Schmidt telescope from the University of Uppsala has been erected by the Commonwealth Works Department, buildings for the photographic zenith tube have been completed, and notable improvements to the grounds have been made.

Hartmann tests at the prime focus of the 74-inch telescope with silvered mirror were carried out by Professor Woolley, Dr Hogg and Mr Gottlieb. An aluminizing plant is about to be installed. The 50-inch reflector has been set up as a Gregorian hut, and although the telescope has been used by Dr Eggen for photoelectric work further work remains to be done to bring it to regular operating conditions.

Spectroscopy.—Over 500 spectra have been obtained by Drs Buscombe, Gollnow, Hagemann, Heintz and Przybylski using the 3-prism spectrograph on the 30-inch Reynolds reflector. This programme includes stars from the Scorpio Centaurus cluster, stars from the N30 Catalogue and some variables. Mrs de Vaucouleurs obtained and measured 98 microphotometer traces of spectra taken by Dr Heintz to determine the equivalent width of the Ca II K line in late type stars.

Photometry.—A comparison between the light from a standard lamp and that from a number of bright stars has been completed by Dr Gascoigne aided by Dr Heintz. Dr Hogg has carried out some check measures of the surface brightness of the Small Magellanic Cloud as well as further observations on the light variation of Sigma Scorpii and three colour photoelectric measures of a number of bright stars and the Kappa Crucis cluster. Dr Gascoigne completed photoelectric observations of some brighter galactic cepheids and continued to observe objects in the Magellanic Clouds. Dr Eggen using either the 20-inch or 50-inch reflector discovered variability in CoD -41° 1776 (RR Lyrae type), Co -48° 13982 (RR Lyrae type), BD -2° 127 (unknown) and BD -20° 345 (W Ursae Majoris type). Mr Rodgers has been engaged on in-focus photographic photometry of 104 blue supergiants in the Large Magellanic Cloud and has also obtained a number of plates in three colours of the Coal Sack region to investigate absorption in this area.

Globular clusters.—Professor Woolley assisted by Mr Rodgers and Mrs Robertson carried out theoretical investigations of equilibrium in globular clusters. Dr Gascoigne measured the surface brightness of the globular clusters Omega Centauri and 47 Tucanae.

Stellar atmospheres.—Dr Przybylski continued his theoretical investigations of stellar atmospheres.

Time and meridian astronomy.—Mr Abraham continued in charge of time observations and results were obtained as usual. The arrival times of pulses on standard frequencies were measured in connection with the quarterly experiments arranged by Commission IIIC of URSI. Drs Schmeidler and Heintz completed their programme of the measurements of declinations of southern stars with the Munich vertical circle.

Personnel and visitors.—In addition to the resignation of Professor Woolley that of Dr D. W. N. Stibbs is recorded. Drs Schmeidler and Heintz returned to Munich Observatory after completing their programme. Dr O. J. Eggen (Lick Observatory) arrived in October as guest investigator to carry out a programme of variable star observations. Professor Dirk Brouwer (Yale) is at Mount Stromlo during the installation of the Yale-Columbia refractor.

Riverview College Observatory, Riverview, N.S.W.

(*Director, T. N. Burke-Gaffney, S.J.*)

During 1955 plates taken for the variable star programme numbered 460, somewhat less than last year, since the season during which most work is usually done happened, this year, to be poor for photographic purposes. On the other hand, an unusually large number of occultations was observed. Reprints 8 and 9 were distributed, and the first of a new series (Series II) of Reprints, together with Geophysical Papers 5 and 6, were issued.

The customary provision of astronomical and geophysical information was provided to interested parties; much use was made of library facilities under the inter-library exchange scheme; and, at different times, three students spent some time at the Observatory on post-graduate work.

Staff shortage continues to retard the rate of production, particularly with regard to publications; nevertheless, reasonably satisfactory progress is being made.

Sydney Observatory

(*Director, Harley Wood, Government Astronomer*)

The work on the Astrographic Catalogue has been continued. Volume 35 was printed and distributed and Volumes 33, 36 and 37 are now in the hands of the printer. Several more volumes are ready for publication. Volume 4 of the Melbourne Section of the Astrographic Catalogue was printed and distributed under the direction of Dr J. Baillaud. Volume 5 is at present being printed in Paris and Volume 6 is complete in manuscript. Work is going forward on Volume 7. These volumes are being seen through the press by Dr J. Baillaud using resources granted by the International Astronomical Union.

The programme of observations of occultations predicted in the Nautical Almanac has been continued. The results for 1954 have been published and those for 1955 are reduced. The photographic observation of double stars has continued.

We continue to observe minor planets which culminate south of the equator and are now making precise observations of some of the minor planets selected

for purposes of fundamental astronomy. In 1955 we secured a set of observations of Ceres.

The civil and educational work of the Observatory has continued as in previous years and from March to May a series of lectures on Astronomy was given under the auspices of the Department of Tutorial Classes of Sydney University.

Wide angle photographs are being taken at Sydney Observatory for the preparation at Yale University Observatory of Catalogues of stars in zones of the southern sky. Professor D. Brouwer, Director of Yale University Observatory has been in Sydney since September in connection with this programme.

Radiophysics Laboratory, Sydney

(*Director, Dr E. G. Bowen*)

The Radio Astronomy Group in this Laboratory, directed by Dr J. L. Pawsey, has continued its observations and theoretical work in the main fields of radio astronomy.

1. *Cosmic radio waves*

(*a*) *Continuous emission.*—Detailed studies of a number of interesting objects, emission nebulae, normal galaxies, etc., have been completed using the 1500-foot " Mills Cross ", which has a resolution of 50 minutes of arc at its operating wave-length of 3·5 metres. A general survey of the sky south of declination $+10^\circ$ is proceeding. On a wave-length of 50 centimetres a coarser galactic survey (resolution 3°) has been completed. A second Mills Cross with arms 3500 feet long, which will have a resolution of $1^\circ{\cdot}5$ at 15 metres, is nearing completion. Observations of the angular size of discrete sources on a wave-length of 3 metres using an interferometer with a base-line of several miles are continuing.

In the course of the 3·5-metre observations, which are still very incomplete, some 1300 discrete sources have been located. These appear to show grave discrepancies with the Cambridge observations. These discrepancies will be checked carefully. Other observations of interest are that no radiation was detected from globular clusters or common novae, that, among normal galaxies, SB and SC types appear to be more effective radio emitters, and that the radio emission from optical emission nebulae, some seen in emission, others in absorption, appears to be thermal in origin. A study of the central region of the Galaxy has shown that the detailed distribution of radio emission at 3·5 metres differs markedly from that at centimetre wave-lengths and re-emphasizes the need for pencil beam techniques.

An interesting new observation is that a discrete source (09S1A in Hydra) shows greater fluctuations than do other sources. The cause of the excess Hydra fluctuations, perhaps ionospheric scintillations or intrinsic variations, has not been found.

(*b*) *Atomic line emission.*—A survey of 21-centimetre line emission, near the plane of the Galaxy, has been completed and the results will be used to complement those of the groups working in the northern hemisphere.

2. *Radio emissions from the Sun.*—The series of high-resolution observations of the Sun at 21-centimetre and at 60-centimetre wave-lengths has been completed. A new aerial system consisting of two multiple interferometers (each having 32 18-ft parabolic aerials) arranged as a " cross " is in course of construction. Whereas the former system scanned the Sun in various directions with fan-shaped beams, the new system is designed to scan the Sun, television-wise, with a steerable pencil beam 3 minutes of arc wide at a wave-length of 21 centimetres.

Observations have continued with the radio spectrometer on the spectrum and polarization of radio bursts from the Sun.

3. *Radio emission from Jupiter.*—Following the announcement that a group at Washington had detected radio emissions from the planet Jupiter, observations of Jupiter commenced at Sydney. In addition, a search was made through old records, and evidence was found for radio emissions from the planet. It was discovered that for a period of some weeks all these emissions appear to have originated from one region on the planet.

4. *Theoretical studies.*—Theoretical work has centred largely on problems of the origin and transmission of electromagnetic waves in an ionized gas—such as is found in the Sun's atmosphere and in the vicinity of hot stars. An investigation of the harmonic structure of longitudinal plasma oscillations has been made, and the results have been used to show the mode of origin of " harmonic bursts " from the Sun.

The question of the growth of electromagnetic waves in an ionized medium has been investigated and it has been found that a number of proposed mechanisms for this are untenable. The various types of waves that may be generated in an ionized medium in the presence of a magnetic field have been studied, and found to reduce to only four types.

5. *Giant radio telescope.*—The construction of a large pencil-beam radio telescope in Australia has been made possible as a result of generous donations of $250,000 each from the Carnegie Corporation of New York and the Rockefeller Foundation, and a promise from the Government of the Commonwealth of Australia to meet half the cost. As a first step towards the realization of this instrument a design study is being undertaken by a prominent firm of consulting engineers in Great Britain.

6. *Publications during* 1955

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McGee, R. X., Slee, O. B. and Stanley, G. J., " Galactic Survey at 400 Mc/s between Declinations $-17°$ and $-49°$ ", *Aust. J. Phys.*, **8**, 347–367, 1955.

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Swarup, G. and Parthasarathy, R., " Solar Brightness Distribution at a Wave-length of 60 Centimetres. Part I—The Quiet Sun ", *Aust. J. Phys.*, **8,** 487–497, 1955.
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Wild, J. P., " Outbursts of Radio Noise from the Sun ", *Vistas in Astronomy*, ed. A. Beer, Pergamon Press, London, 1955, Vol. 1, pp. 573–584 (Special Supplement No. 3 to *J. Atmos. Terr. Phys.*).

Perth Observatory

(*Director, Mr H. S. Spigl, Government Astronomer*)

Approval has been granted to the appointment of an assistant astronomer and junior general assistant and steps have been taken to advertise the positions. Attention is now being given to an overhaul of the main instruments, and approval has been obtained to purchase a Shortt free pendulum clock, a photoelectric photometer, and an instrument lathe. The Observatory buildings have been renovated and the grounds restored to good order.

The Western Australian Standard Time service has been maintained. The ONOGO signal, broadcast from Applecross Wireless Station, and the usual hourly and other time signals distributed.

The Milne–Shaw and Lamont vertical seismograph recordings were analysed and details of 148 earthquakes recorded distributed by quarterly bulletins to the 58 co-operating stations. Preliminary reports of strong movements within 5000 km of Perth were cabled to the U.S. Coast and Geodetic Survey through the American Consulate.

The results of nineteen occultations were sent to H.M. Nautical Almanac Office for inclusion in the discussion. Tide tables for Port Hedland for 1956 with appropriate astronomical data were completed for printing, and astronomical phenomena compiled each month for various places throughout the State. Information was frequently sought and supplied to the press, radio, and the public, and for legal and other purposes.

Night demonstrations and Tuesday afternoon visits continue to be popular, three evening visits per week on an average being available to the public.

Geophysical Observatory, Christchurch, N. Z.

(*Superintendent, Dr J. W. Beagley*)

Installation of the J28 automatic ionosonde at Rarotonga was completed early in the year and satisfactory continuous recording commenced. Ionosondes were operated at Christchurch and Campbell Island as usual. A break in the Christchurch continuity of recording occurred from May until August while a permanent hardwood mast was under construction replacing a mast irreparably damaged by gale at the end of April. Improvement in the quality of records was attained with the new mast and aerials.

A panoramic ionosonde constructed at Dominion Physical Laboratory, Wellington, was installed at Godley Head Station and is being further developed by Canterbury College Industrial Development Laboratory and Observatory physicists in Christchurch. Two further panoramics modelled on the prototype are being constructed for use at McMurdo Sound and Rarotonga during the 1957–58 International Geophysical Year.

Investigations into the electron distribution of the ionosphere have continued. The method evolved at the Observatory during 1954 of analysing virtual height records to obtain true heights of ionospheric layers has been utilized during 1955. Diurnal curves of maximum electron density and critical frequency have been compiled and a structure of the F_2 layer proposed. Analysis of geomagnetic sudden commencement amplitudes has been completed and deductions concerning the effect of the ionosphere in modifying sudden commencement impulses considered.

Continuous recording of cosmic radiation at Christchurch has been maintained. The Blackett MU_2 recorder has continued the E–W asymmetry experiment and the Compton Bennett ionization chamber has operated as usual. During the International Geophysical Year the MU_2 recorder will be utilized for vertical intensity recording at Christchurch and the results compared with a meson telescope under construction at the Observatory for installation at Invercargill on the other side of the "energy cut-off" latitude from Christchurch.

Carter Observatory, Wellington, N.Z.

(*Director, Mr I. L. Thomsen*)

From February to December, lectures and telescope demonstrations on clear Friday evenings were given as in former years, and the attendance rate has been maintained. Many additional lectures have been given to societies and clubs, and popular newspaper articles supplied as necessary.

As the headquarters of the Royal Astronomical Society of New Zealand, the Observatory has continued to give as much assistance as possible to amateurs, and the lecture room was made available for meetings.

The pendulum clock has been regularly checked by time signals originating from the Seismological Observatory.

An 8-inch micrometer theodolite was obtained from the Ministry of Works.

Sunspot observations have been maintained using a 5-inch refractor for projection drawings on a 25 cm disk and the 9-inch refractor for photographs on a scale of 10 cm diameter. These, together with observations from several selected amateurs, have been used to deduce Wolf sunspot numbers reduced to the Zürich scale. Detailed reports were forwarded to the Zürich Observatory.

Observations with the Hale spectrohelioscope on loan from Mt Wilson and Mt Palomar observatories were continued, and the increase in general chromospheric and solar flare activity was very obvious. Reports have been forwarded to Meudon Observatory.

Auroral activity showed a corresponding increase with solar activity and displays began to be visible from the New Zealand mainland. Activity showed a remarkable increase at Campbell Island.

A complete study of 2334 auroral displays recorded from 1930 to 1954 was nearing completion at the end of the year, under a contract with the Air Force Cambridge Research Centre, U.S.A.

Short-term ionospheric disturbance forecasts were issued to the Post and Telegraph Department, New Zealand Broadcasting Service, and the Royal New Zealand Navy.

A considerable amount of time has been spent on work connected with the International Geophysical Year.

Canterbury University College Observatory, N.Z.

(*Director, Mr K. W. Roth*)

The observatory consists solely of a nearly hundred-years-old six-inch Cook refractor in German equatorial mounting with simple clockwork drive. No time piece, camera or spectroscope is included in the equipment.

Moreover, the Observatory is unfavourably situated in the centre of the city. For these reasons no serious work has been attempted with this outfit. Surveying students are being trained in elementary observations and the public is admitted regularly once a week. The attendance is on the average quite good and not infrequently the little observatory is overcrowded.

Research work being undertaken is on meteor streams and depends entirely on Radar equipment located outside the city.

Godlee Observatory, College of Technology, Manchester

(*Curators, Manchester Astronomical Society*)

During 1955 activities at Godlee Observatory have continued on their usual lines, although somewhat interfered with by the structural alterations in connection with the new wing of the College of Technology. Thursday evenings have been reserved for Members of the Manchester Astronomical Society who have attended in good numbers. Observational work has been carried out whenever weather permitted, and on other evenings there have been discussions on a variety of astronomical topics. Facilities have been provided for parties

from a number of educational and cultural organizations to visit the Observatory, and these visits have proved extremely popular. Also there has been a demand for astronomical lectures, which have been provided by the Wardens.

Solar observations have been made daily when the weather permitted, and members of the Manchester Astronomical Society have sent in solar drawings made with their own instruments to supplement those made at the Observatory.

A series of observations of comet 1955 g was made, and also planetary and lunar observations and photographs, and double star measurements.

Mr R. Barker's Observatory, Cheshunt, Hertfordshire

The chief work with the 12·6-inch Calver equatorial was an overhaul of many difficult lunar clefts in the region of the great Hesiodus Cleft and Cichus. Some of these have not yet been confirmed, and fuller details appear in the March issue of *The Moon*, **4**, No. 3, a privately owned journal of the B.A.A. Lunar Section.

Dr John L. Haughton's Observatory, Charmouth, Dorset

During the first half of the year eight lunar occultations were observed and 50 visitors were admitted. The Observatory was dismantled in early August, and the instruments were brought down to Littleton, near Winchester, where it is hoped to re-erect them in the near future.

Mr M. B. B. Heath's Observatory, Kingsteignton, S. Devon

Some minor repairs to the dome were carried out. The Sun was observed on 161 days. Daylight observations were made of Mercury on 15 days and of Venus on 81 days. Jupiter was observed on 18 nights during which 25 satellite phenomena were timed. Saturn was observed on 20 nights.

Mr F. M. Holborn's Observatory, Peaslake, Surrey

During 1955, 2418 observations were made of 73 variable stars and novae on 187 nights, and work on comparison star sequences was continued. The Sun was observed on 227 days for spot counts and naked-eye spots. A few physical observations were made of planets and comets.

All records were communicated to the British Astronomical Association except those of γ Cassiopeiae which were sent to the Norman Lockyer Observatory.

Mr Patrick Moore's Observatory, East Grinstead, Sussex

Regular lunar observations with the 12½-in. reflector have been carried out during 1955; particular attention has been paid to the south-eastern limb region, where the published maps and charts are in general unsatisfactory. Routine observations of Jupiter and Saturn have also been made. All results have been reported to the British Astronomical Association.

A 6½-in. reflector has been added to the equipment of the Observatory.

Mr G. E. Patston's Observatory, Eastbourne, Sussex

The 12-inch reflector was moved from London in 1952. After an interruption of nearly 3 years a site has been found, close to the foot of Beachy Head, and observations resumed on the 45 Long Period and Irregular Variable Stars on the Observatory's programme, principally on Z Cam- and U Gem-type

stars. Of the 113 observing nights, 47 were really fine, occasionally revealing magnitude 15. A weight drive must replace a former electric drive as current is not available. Records are sent to the British Astronomical Association.

Mr F. J. Sellers' Observatory, Muswell Hill, London

Casual observations only have been made during the year from which there is nothing of special interest to report. It is hoped that more continuous work will be possible during the coming solar maximum.

Dr W. H. Steavenson's Observatory, Cambridge

Photometric observations of faint novae, especially Nova Persei, have been continued with the 30-inch reflector.

Physical observations were made of comets 1954 h (Baade), 1955 e (Mrkos), 1955 f (Bakharev) and 1955 g (Honda).

Throughout the year the telescope was in frequent use for demonstrations to members of the University and other visitors.

Dr R. L. Waterfield's Observatory, Ascot, Berkshire

During the year, 37 plates were exposed on the comets Baade, 1954 h, (6); Mrkos, 1955 e, (6); Bakharev, 1955 f, (4); Honda, 1955 g, (19); Perrine-Mrkos, 1955 i, (1); and Haro-Chavira, 1955 k, (1), for the estimation of magnitudes and the recording of physical features. Several unsuccessful attempts were made to recover the periodic comet Olbers, and another exposure helped to confirm the non-existence of the object reported by Renner. The results were communicated to the comet section of the B.A.A. Twelve lunar occultations were observed and communicated to the H.M. Nautical Almanac Office. The writer also attended the meeting of the I.A.U. in Dublin and took part in the discussions of Commission 15.

Dr H. P. Wilkins' Observatory, Bexleyheath, Kent

Lunar observations have continued with the 15-inch reflector particularly in the Libratory Regions. The results appear in the large work on the Moon recently published in joint authorship with Patrick Moore.

Jupiter, Saturn and Uranus were also observed. Spot transits on Jupiter were recorded together with magnitude estimates during the appulse of Jupiter and Uranus. A very large number of visitors have used the instrument on Saturday nights several of which have acquired a genuine interest in astronomy and joined the British Astronomical Association.

With the spectroscope a number of solar prominences have been recorded and these were supplemented by observations with the Lyot Monochromator at Meudon.

REPORTS ON THE PROGRESS OF ASTRONOMY

MINOR PLANETS

This report for the years 1954 and 1955 succeeds the last one given in *M.N.*, **114,** 358. In general, the work continues at a normal and satisfactory rate. There were 164 and 160 MPC's issued in these years, and the number of provisional designations was 364 and 287 thus far. Permanent numbers were assigned to 20 planets, 11 as a result of identifications established between planets observed in different years. This is still a fruitful field of investigation, although the law of diminishing returns may be expected to take effect in the next few years.

A programme of electronic computation on the NORC by means of Hansen's method has been completed and applied to the first four minor planets and about a dozen other cases. The only limitation is that the starting date must be JD 2430000·5. The perturbations by Venus to Saturn at 10-day intervals, from 1920 to 2000 AD and all the disturbed, rectangular co-ordinates are computed for one planet in 15 minutes. This has permitted the continuation of accurate ephemerides of Ceres, Pallas, Juno, and Vesta beyond 1960. The Minor Planet Centre proposes to experiment next with Musen's method (*Astr. Jour.*, **59,** 267) for large scale perturbation computations.

The Dublin IAU meeting demonstrated the increasing effectiveness of co-operation among the various centres interested in this field of work. The Rechen Institut at Heidelberg will prepare a revised edition of the Identifizierungsnachweis. A new catalogue of elements of unnumbered planets will be prepared at the Cincinnati Observatory, with the co-operation of numerous volunteers. The annual ephemeris volume published at Leningrad now gives the names in Latin letters, as requested by many users. The number of ephemeris corrections has been reduced to insignificance, since the computations from other centres are now included in the printed volume. The translation of the Introduction to this volume has been prepared each year by Dr P. Musen. The preparation of the Minor Planet Circulars for publication continues under the immediate supervision of Dr E. Rabe.

PAUL HERGET

SOLAR ACTIVITY

Sunspots.—During 1955 there was a steadily increasing number of sunspots; in fact the rate of rise in activity was at least as rapid as during any previous year following the epoch of sunspot minimum. The Zürich relative sunspot number for the year was 38·0, compared with 33·2 for 1945, the corresponding year of the previous sunspot cycle.

The largest sunspot group during the year passed the Sun's central meridian on June 17 at a latitude 23° S, reaching an area of 1140 millionths of the Sun's hemisphere on June 17, though it may better be regarded as comprising two groups close together with separate development. Many small flares and a few larger flares were observed in the vicinity.

In January a spot at latitude 35° N reached an area of 1000 millionths (Jan. 8). This was the largest spot recorded at as high a latitude in the past eighty years.

There were 44 spotless days during the year, of which 28 were during the months February to April. Sunspot numbers increased during the second half of the year so that the mean monthly Zürich sunspot number for November was 90 and for December 77. Solar flares became frequent after May but none of outstanding intensity was reported. Twenty-nine sudden enhancements of long-wave atmospherics were recorded at Herstmonceux, of which only two occurred before May 27. Also a number of short-wave Dellinger fade-outs were reported by Cable and Wireless Ltd. during the second half of the year.

Terrestrial magnetic activity was generally low throughout the year. One or two small storms occurred and there was a slight 27-day recurrence tendency during March, April and May. Otherwise there were no marked M-region storms. Faint aurorae were reported frequently during November and December.

P. A. WAYMAN

Prominences.—With the advance of the new sunspot cycle there has been in 1955 a very great increase in all forms of prominence activity compared to 1954. The mean daily areas and numbers of calcium prominences at the limb as derived from photographs taken at Kodaikanal are given below :

	Area in square minutes					Number				
1955	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	2·21	1·14	1·59	1·76	3·35	4·24	3·28	3·71	3·81	7·52
July–Dec.	2·47	1·96	2·01	2·42	4·43	4·60	3·77	4·09	4·28	8·37
Whole year (weighted mean)	2·32	1·51	1·78	2·05	3·83	4·40	3·50	3·88	4·02	7·90

Compared with the previous year prominence activity as represented by areas shows an increase of 154 per cent while the numbers show an increase of 47 per cent.

The distribution of areas in five-degree ranges of latitude shows maximum activity in the zones 45°–50° in the northern hemisphere and 40°–45° in the southern hemisphere with a secondary maximum between 10° and 15°. The zone of maximum activity in the northern hemisphere has advanced nearly 10 degrees towards the pole and the peak in the southern hemisphere has moved five degrees nearer the pole from their positions in 1954. Greater activity than in the previous year is observed beyond latitude 50° in both the hemispheres. The western preponderance in prominence areas and numbers noticed last year continues.

Only one metallic prominence was observed during the year.

Doppler shifts of the H-alpha line observed in prominences and absorption markings with the prominence spectroscope and the spectrohelioscope are given below :

	North	South	East	West	To red	To violet	Both ways	Total
Prominences	58	43	52	49	6	..	95	101
Dark markings	8	1	5	4	1	1	7	9

The heights of 19 prominences were measured in H-alpha, D_3 and H-beta lines with the prominence spectroscope. These were compared with the

corresponding heights in the K line as obtained from the spectroheliograms. The average heights were :

K	H-alpha	D_3	H-beta
74″·7	72″·4	60″·9	54″·3

Four instances of sudden disappearance of absorption markings and prominences were observed during the year.

The mean daily areas and numbers of hydrogen absorption markings on the disc as obtained from Kodaikanal records are given in the following table. The areas and numbers in this table have been derived from the values computed for each five-degree zone for the four quadrants NE, NW, SE and SW of the disk.

	Area in millionths of the Sun's visible hemisphere (uncorrected for foreshortening)					Number				
1955	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	902·4	376·5	686·3	592·6	1278·9	6·20	2·62	4·66	4·16	8·82
July–Dec.	1623·4	830·5	1108·0	1354·9	2453·9	10·01	4·90	6·78	8·13	14·91
Whole year (weighted mean)	1234·4	585·5	880·6	939·3	1819·9	7·95	3·67	5·63	5·99	11·62

Compared with the previous year there has been an abnormal increase in activity in both areas and numbers, the increase in areas being about 231 per cent and the increase in numbers 117 per cent.

The distribution of areas in latitude shows a pronounced peak of activity between latitudes 45° and 50° in both the north and the south hemispheres with a secondary maximum between latitudes 30° and 35° in the southern hemisphere. Here again both areas and numbers show a western excess.

A. K. DAS

COMETS (1955)

Fifteen comets were under observation in 1955. These included five new ones and three periodic comets, as well as the two annual comets and five of the discoveries of the previous year.

Comet Schwassmann–Wachmann (1), which is normally described as " magnitude 18, nearly stellar ", showed another of its remarkable outbursts of light in July. It was photographed by H. M. Jeffers and C. B. Stephenson on July 12 with the Crossley reflector at Lick, and showed an elongated or double nucleus in a coma of 80″ diameter, magnitude 14·5, with 60-minute exposures. Jeffers observed the comet visually on the following nights, estimating the magnitude as 13 on July 13 and 16 on July 15. The comet was then close to two bright stars, and it was not possible to obtain satisfactory spectra. No further activity was reported up to mid-September, when the comet was near the Sun, but it was recorded several times by van Biesbroeck at McDonald in October. On the 14th it was as faint as usual, but on the next plate, taken on October 19, it had risen to magnitude 12, and appeared as an almost stellar coma. On October 21 it had faded only slightly but was more diffuse.

The other annual comet, Oterma, was photographed at Lick in July, October and November, and remained as a stellar object of magnitude 18–19. It was recorded at Yerkes in August by van Biesbroeck, who also photographed the comet with the 82-inch reflector at McDonald in October and November, when it appeared as a small, well-defined coma of magnitude 17.

1954 e, periodic comet Faye, was recorded at Yerkes on March 13 at low altitude, and then appeared as a diffuse coma of magnitude 15, with a faint tail in p.a. 30°. It was recovered in the morning sky after conjunction with the Sun, and on Lick photographs taken on October 25 and 28 it was a slightly diffuse object of magnitude 18·5. It was again recorded on 1956 March 16, when the magnitude was 19. (*Observations* 1954 *July* 25 *to* 1956 *March* 16)

1954 g, periodic comet Schwassmann–Wachmann (2), remained during January and February at about magnitude 13. A 30-minute exposure at Lick on January 27 showed a round coma 0′·8 in diameter, with strong central condensation. A series of observations by Max Beyer at Bergedorf report a similar appearance in February. In April, van Biesbroeck at McDonald reported a slender tail over 1′ in length; on April 25 it was estimated at 1′·5 in p.a. 110°. The last observation appears to be a Crossley photograph, taken at Lick on May 25 with a 16-minute exposure, showing a small image of estimated magnitude 17·5. (*Observations* 1954 *July* 28 *to* 1955 *May* 25)

1954 h, Baade, was easily observable throughout the year. Steavenson, at Cambridge, reported the comet as having a coma about 30″ diameter, total magnitude about 12 on March 10; photographs by R. L. Waterfield on March 13 and 19 show a short broad tail 2′ long in p.a. 330°. In continuation of his useful work on cometary magnitudes, Max Beyer at Bergedorf made 37 observations of this comet, from February 21 to May, and September to the end of the year. The comet showed progressive increase of brightness from 12·7 in February to 12·0 in mid-November, while the coma, which was about 1′·8 in diameter in the earlier months, had become smaller by September and afterwards increased in size, remaining well condensed. On the photographs taken at Lick (Roemer) during the summer the comet showed many interesting features in the structure of the persistent tail. In August and September a jet which appeared on the south side of the nucleus was swept back into a fairly broad tail 5′ in length in p.a. 20°. The comet was then an easy object in the Crossley reflector, but the stellar nucleus shown on the photographs was estimated at magnitude 16. The same appearance continued through October and November, but the comet brightened somewhat in November (Beyer, Roemer) and could then be seen visually in the 4-inch finder of the Crossley telescope. On November 25 there was definite indication of a short broad tail 1′ long at 350°, previously suspected at the end of September. The comet was still under observation in 1956 February. (*Observations* 1954 *July* 31 *to end of* 1955, *continuing*)

1954 i, van Biesbroeck, was photographed by Elizabeth Roemer at Lick at the end of September, and again in October and November. Exposures of 90–100 minutes with the Crossley reflector showed a well-condensed object of magnitude 19·5. (*Observations* 1954 *September* 1 *to* 1955 *November* 7)

1954 k, Haro-Chavira, which was discovered at the end of December, 1954, was not seen at Lick and Yerkes until mid-January. The comet was conveniently placed for observation and had still a year to run before perihelion passage. The perihelion distance, however, is large, and the comet was never a bright object. In February (Lick) the coma was small and round, with central condensation, magnitude 16·5, and similar reports were made throughout the apparition. In April at McDonald, van Biesbroeck recorded a faint broad

tail, 1′ long in p.a. 170°, and a similar structure was shown on Crossley 30-minute plates on August 19. At the end of November the coma was still fairly well condensed, magnitude 16·5 (Roemer) and the comet was still under observation in the early months of 1956. (*Observations* 1954 *December* 17 *to end of* 1955, *continuing*)

The new comets discovered during the year were as follows :

1955 a, was found on plates taken on March 22 by Robert G. Harrington and George O. Abell with the 48-inch Schmidt telescope for the NGS-Palomar Sky Survey. The comet was then a diffuse object of magnitude 17, with central condensation and a short tail. Two further Palomar positions were obtained, and Cunningham computed an orbit and ephemeris which enabled this faint comet to be found again when the Moon was absent. Van Biesbroeck, at McDonald on April 24, described the comet as having a nucleus of magnitude 19·5, surrounded by a vague nebulosity. When last seen at Lick on May 18 the magnitude was estimated at 19·2 (Crossley reflector, 120-minutes exposure). This comet must be intrinsically very faint, since its distance at the end of March was only one unit from the Earth and two units from the Sun. (*Observations March* 22 *to May* 18)

1955 b was also found on 48-inch Schmidt plates taken by G. O. Abell for the Sky Survey on April 13. The diffuse image showed central condensation and a short tail. Elements by Cunningham showed a parabolic orbit with retrograde motion and the large perihelion distance of 4·5, and although more than a year past perihelion passage, the comet was much brighter than 1955 a, and has been widely observed throughout the year. At Lick, it was photographed in April, May and June, still showing the persistent tail, but fading from magnitude 16·5 to 17·5. At McDonald on April 21–25, van Biesbroeck reported the comet as a small round coma, magnitude 16, with a tail extension about 1′ long in p.a. 130°. By July it had faded to a diffuse coma no brighter than magnitude 18 (Yerkes). After conjunction with the Sun, it was photographed again with the Crossley reflector at Lick on November 25–26 and then showed a well-condensed nucleus of magnitude 17·5, with a fan-shaped tail about 1′ long in p.a. 80°. The comet was still under observation at Lick on 1956 March 20. (*Observations April* 13 *to end of year*, *continuing*)

1955 c, periodic comet Ashbrook–Jackson, 1948 IX, was recovered by van Biesbroeck at McDonald before dawn on April 24. The comet has a perihelion distance of 2·3 and a moderate eccentricity of 0·39, and it had been suggested that it might well be within reach of large instruments, although perihelion passage did not occur until 1956 April 5. Two B.A.A. computers made predictions of the return, M. P. Candy using a Cowell scheme, and W. E. Beart using Merton's method, with almost identical results, and an ephemeris was published in *UAIC* 1487. The comet was found close to the predicted position as a slightly diffuse object of magnitude 17. It was then in south declination 38° and although recorded several times at Yerkes observation from the northern hemisphere was difficult. It was photographed by Bruwer with the Franklin Adams star camera at Johannesburg in May June and July (magnitude 13) and when the comet came north again in September, several plates were taken at Lick with the Crossley reflector. On September 21 the

comet was described by Miss Roemer as having a nearly stellar nucleus of magnitude 17·0 with a faint coma mainly on the north-east side. The last observation reported is that of van Biesbroeck at McDonald on October 12, when the comet appeared as a 12th magnitude coma with a short tail in p.a. 340°. (*Observations April 24 to October 12*)

1955 d, periodic comet Whipple, 1933 IV, was recovered by Miss Elizabeth Roemer on May 25 on plates taken with the Crossley reflector at Lick. It was then a diffuse object of magnitude 18 and was almost exactly in the place predicted by C. Dinwoodie in the *B.A.A. Handbook*. Further observations were made at Lick and Yerkes during the summer, and in this period the comet retained a small coma surrounding a nearly stellar nucleus, but became somewhat brighter. On August 18 van Biesbroeck at Yerkes recorded a faint tail extension in p.a. 250°, the coma being then 8″ in diameter, magnitude 16. At the end of September the comet was faintly visible in the Crossley reflector, and photographs showed a nearly stellar nucleus, magnitude 17·0, surrounded by a coma of diameter 0′·4. The coma had decreased in size by October 24, and on November 12 van Biesbroeck (McDonald) noted a diffuse nucleus with a broad tail towards p.a. 45°, total magnitude 13. The comet was still under observation in 1956 February (Yerkes) but was then diffuse and faint (magnitude 18) and moving into the evening twilight. (*Observations May 25 to end of year, continuing*)

1955 e was discovered on June 12 by Antonin Mrkos at his private observatory on Lomnický Štít. This is the second highest peak (2634 m above sea level) of the Tatra mountains, and is connected by a rope railway via Skalnaté Pleso with Tatranská Lomnica. Routine searches are made by Mrkos with Somet-Binar binoculars 25 × 100, and the number of comets with which his name is associated bears tribute to the value of this work. Comet 1955 e was a naked-eye object at the time of discovery, and was observed two days later at Lick with binoculars and the 12-inch refractor. A tail 2° long was seen, and the visual magnitude was estimated at 4. At Oxford on June 16, Merton described the comet as having a round coma 4′ diameter, sharply condensed centrally, and with total magnitude $5\frac{1}{2}$; the tail could be traced in the finder for $\frac{1}{2}$° in p.a. 340°. Beyer at Bergedorf reports a similar appearance, and his records show that the comet faded somewhat rapidly from magnitude 4·8 on June 17 to 6·9 on July 9. On this last date, the coma 6′ diameter had a nucleus of magnitude 11·0 and the tail had become very faint, $\frac{1}{2}$° long in p.a. 52°.

Many observations were made in Europe and America, and these include spectra by Kresák at Skalnaté Pleso and by Elizabeth Roemer at Lick. A ten-minute exposure with the Crossley reflector on August 13 showed a well condensed nucleus, magnitude 14, in a round coma 2′ in diameter. The elements of the orbit are very similar to those of the comet of 1707, with an inclination of nearly 90°. The last observations appear to be a Crossley photograph of September 8, when the comet was diffuse and had sunk to magnitude 18; and an observation by van Biesbroeck at Yerkes on the same day, in which the comet is described in somewhat similar terms. (*Observations June 12 to September 8*)

1955 f was discovered by A. M. Bakharev at Stalinabad on the night of July 13 in the course of meteor observations with " Asembe " binoculars × 20.

It was independently discovered by two amateurs, Lewis Macfarlane and Karl Krienke, at Seattle, Washington, about half a day later, while observing with a $3\frac{1}{2}$-inch refractor and an 8-inch reflector. At the time of discovery the comet was of the 8th magnitude, and was moving north-west in Pegasus. It had just passed perihelion (July 11) and grew steadily fainter during the succeeding months, but was widely observed. On the nights of July 17–19 photographs taken at Lick with the 20-inch Carnegie Astrograph show a symmetrical coma about 2′·5 in diameter, with a well condensed centre, and a narrow tail 20′ long in p.a. 310°. The comet is described as about 5′ diameter as seen in the 4-inch finder, while a faint stellar nucleus was visible under high magnifications in the 10-inch guide telescope. Observing visually with the 36-inch refractor at Lick on July 20, Jeffers described the comet as 3′ diameter with a stellar nucleus magnitude 15; a similar appearance was given on July 29. On August 12, van Biesbroeck at Yerkes described a sharp nucleus in a coma of 4′ diameter, with a slender tail about 1° long in p.a. 185°. On August 17, Beyer, using the 26-cm refractor at Bergedorf, assessed the 8′·0 coma at a total magnitude of 8·5 and estimated the nucleus at 12·7. How much these estimates depend on the instrument and method is seen by comparing these values with others at the same period. A 20-minute Crossley photograph on August 25 showed a round coma of diameter 6′, with strong condensation to the centre, while 6- and 8-minute photographs with the same instrument on August 30 show a stellar nucleus of magnitude 14·5 with a nearly symmetrical coma of diameter only 0′·8. The nucleus could be seen visually in the Crossley in spite of moonlight. A valuable series of measures with this instrument was made from July to November, by which time the nucleus had faded to magnitude 17. On November 23, Beyer gave a total magnitude of 13·1, the coma having shrunk to a diameter of 1′·6. The comet was observed by van Biesbroeck at McDonald on November 12, when the diffuse tail extended 40″ from the nucleus in the direction 90°; total magnitude 14.

The last observation appears to be that of November 25 (Lick) and photographs taken at Yerkes and Lick in 1956 failed to locate the comet. (*Observations July 13 to November 25*)

1955 g was discovered by Minoru Honda on July 29 at Kurasiki, Japan, as an 8th magnitude object in Orion, and this comet, which moved rapidly northwards, became the brightest comet of the year. Early observations were made at Cordoba and Lick, and from mid-August the comet was widely observed.

On August 21 van Biesbroeck recorded a large diffuse head 10′ diameter, with central condensation, total magnitude 6·5. There was a complex tail, a narrow faint filament extending 30′ in p.a. 330°, and a broad sector of material between 270° and 330° extending to 15′ from the nucleus. In early September the comet brightened appreciably (Beyer gives magnitude 5·7 on September 4) and variations in coma formation and in the structure of tails and streamers were noted by Elizabeth Roemer at Lick. Spectra were obtained at this period at Lick and Skalnaté Pleso. On Crossley plates taken on September 21, the nucleus appeared double, with two nearly equal, sharply condensed components separated by 5″ in p.a. 300°. By September 26 the brighter component had become diffuse and it had disappeared by October 5, the other remaining clearly defined. The double nucleus was also reported by Mitani at Kyoto

(*UAIC* 1538). The second component of the nucleus faded during October, but the faint tail remained. At Lick, in mid-November, the magnitude was estimated at 16; van Biesbroeck at McDonald on November 12 gives the same value, and mentions the tail, 2′ long in p.a. 70° as being still visible. Beyer, at Bergedorf, reports an observation on November 20, but photographs at Lick in 1956 failed to locate the comet. (*Observations July 29 to November 20*)

1955 h was a reported discovery by Rev. C. J. Renner of Castilia, Ohio, but searches by many observatories failed to find any comet in the reported position.

1955 i was another discovery by Mrkos, but this comet is undoubtedly a return of P/Perrine, which was last seen at its 1909 return. Although abandoned by B.A.A. computers, the comet had been studied by Haségawa, who gave three ephemerides in *UAIC* 1488, 1505. When found by Mrkos on October 19, the comet was, however, outside the range of these predictions, and appeared as a diffuse object of magnitude 9—some five magnitudes brighter than was expected. The photographic magnitude (Lick) was, however, estimated at 14·5, and no nucleus was visible even with the Crossley reflector. The comet faded rapidly at the end of October, being estimated at magnitude 11 on October 24, and 16 on November 14 (van Biesbroeck) and 18·3 on November 25 (Roemer). A faint tail 3′ long in p.a. 290° is described by Miss Roemer on October 24 and 27 (Crossley reflector, 30-minute exposures). Although at this time estimated at magnitude 16 on the photographs, the comet was visible in the 4-inch finder after moonset. It was still under observation in February 1956. (*Observations October 19 to end of year, continuing*)

Unsuccessful searches were made during the year at Yerkes and Lick for periodic comet Forbes in June and July, and at McDonald in April for periodic comet du Toit. Several observatories made searches for periodic comet Olbers, but this was not recovered until 1956 January, when Mrkos was again the first to detect the object.

The numerical designation of comets (in order of perihelion passage) has been extended by the I.A.U. Bureau (*UAIC* 1533). The list that follows continues that given in *M.N.* **115**, 195, 1955. The perihelion dates (*T*) are from orbits noted in these annual reports.

Comet	*T*	Name	Year and letter
1952 I	Jan. 12·9	Wilson-Harrington	1951 i
II	Feb. 6·7	P/Harrington	1951 k
III	Feb. 10·7	P/Schaumasse	1951 l
IV	Mar. 11·2	P/Grigg-Skjellerup	1952 b
V	June 8·7	Mrkos	1952 c
VI	July 15·3	Peltier	1952 d
VII	Sept. 10·7	P/Comas-Solá	1951 h

The table giving the elements of cometary orbits is arranged as in last year's report. Comets are listed in order of perihelion date; the symbol P indicates a periodic comet, and *p* after the perihelion date that the elements were predicted ones. The perihelion date deduced from observations in such a case will be found in the notes appended.

Elements of

Ref.	Comet	T(U.T.)	q	e
(1)	1928 III P/Crommelin	1928 Nov. 5·0458	0·744935	0·919021
(2)	1933 III P/Giacobini–Zinner	1933 July 15·1468	0·999518	0·716017
(3)	1935 III P/Schw.–Wach. (2)	1935 Aug. 28·5504	2·094829	0·393833
(4)	1937 VI P/Encke	1937 Dec. 27·7531	0·332368	0·849613
(5)	1939 III Jurlof–Akh.–Hassel	1939 Apr. 10·1689	0·528266	0·998482
(4)	1941 V P/Encke	1941 Apr. 17·1426	0·341352	0·846182
(2)	1946 V P/Giacobini–Zinner	1946 Sept. 18·4866	0·995708	0·716782
(4)	1947 XI P/Encke	1947 Nov. 26·3267	0·341016	0·846295
(6)	1948 IX P/Ashbrook–Jackson	1948 Oct. 4·7793	2·311017	0·395537
(7)	1949 VI P/Shajn–Shaldach	1949 Nov. 26·9055	2·234134	0·405164
(4)	1951 III P/Encke	1951 Mar. 16·2089	0·338004	0·847462
(8)	1951 IV P/T.–G.–Kresák	1951 May 9·3714	1·116522	0·640888
(9)	1951 VI P/Pons–Winnecke	1951 Sept. 8·6114	1·160607	0·653246
(10)	1952 IV P/Grigg–Skjellerup	1952 Mar. 11·1414	0·855697	0·703573
(11)	1955 b Abell	1954 Mar. 24·3171	4·500594	1·0
(4)	1953 f P/Encke	1954 July 2·5200	0·338403	0·847302
(12)	1953 g Abell	1954 July 7·3494	0·970385	1·0
(13)	1955 a P/Harrington–Abell	1954 Dec. 18·2090	1·806732	0·506943
(14)	1955 e Mrkos	1955 June 4·1658	0·534389	0·989306
(15)	1955 f Bakharev–M.–K.	1955 July 11·5448	1·428936	1·002788
(16)	1955 g Honda	1955 Aug. 4·0523	0·884611	1·0
(17)	1955 i P/Perrine–Mrkos	1955 Sept. 27·3509	1·154032	0·667499
(18)	1955 d P/Whipple	1955 Nov. 29·885*p*	2·44956	0·355933
(19)	1954 k Haro–Chavira	1956 Jan. 26·9612	4·07392	1·0
(20)	1955 c P/Ashbrook–Jackson	1956 Apr. 5·596*p*	2·324407	0·393761
		1956 Apr. 5·572*p*	2·324410	0·393768

References and Notes to Table of Elements

(1) Comet P/Crommelin, 1928 III. M. P. Candy and J. G. Porter, *B.A.A. Handbook*, 1956. Improved orbit, using all available observations, linked to previous apparition.

(2) Comet P/Giacobini–Zinner, 1933 III and 1946 V. Y. V. Evdokimov, *Ast. Circ. U.S.S.R.*, No. 159.

(3) Comet P/Schwassmann–Wachmann (2), 1935 III. H. Q. Rasmusen, *Pub. Copenhagen Obs.* No. 106. Reprinted here as a correction (see below).

(4) Comet P/Encke. S. G. Makower, *Pub. Inst. Theor. Astr.* (*Leningrad*) IV, 1955.

(5) Comet Jurlof–Akhmarov–Hassel, 1939 III. L. M. Belous, *Ast. Circ. U.S.S.R.* No. 168. From 399 observations covering 39 days.

(6) Comet P/Ashbrook–Jackson, 1948 IX. M. A. Merzlyakova, *MS.* From 92 observations covering 429 days. Perturbations computed back to 1944 show that before a close approach to Jupiter the comet had $q = 3{\cdot}891$, $e = 0{\cdot}199888$ with a period of 10·72 years.

(7) Comet P/Shajn–Shaldach, 1949 VI. A. Dubiago, *Ast. Circ. U.S.S.R.*, No. 164. Definitive, from 66 observations in 5 normal places covering 113 days. The date T for this comet is in E.T.

(8) Comet P/Tuttle–Giacobini–Kresák, 1951 IV. L. Kresák, *B.A.A. Handbook* 1956. From 90 observations of the 1951 apparition, covering 101 days.

(9) Comet P/Pons–Winnecke 1951 VI. M. P. Candy and J. G. Porter, *MS.* Corrected orbit, using 11 observations covering 265 days, and linked to previous apparition.

(10) Comet P/Grigg–Skjellerup 1952 IV. C. Dinwoodie, *MS.* Orbit of 1952 *B.A.A. Handbook* corrected for 5 observations.

Cometary Orbits

Period (years)	ω	Ω	i	Equinox	Epoch of Osculation	Ref.
	°	″	°			
27·90	195·9661	249·9885	28·8832	1928·0	1928 Nov. 20·0	(1)
6·60	171·7717	196·0046	30·6861	1933·0	1933 July 27·0	(2)
6·42	357·9715	126·2916	3·7285	1950·0	1935 Oct. 5·0	(3)
3·30	184·9320	334·8904	12·5503	1950·0	1937 Nov. 3·0	(4)
6490	89·2480	311·4312	138·1153	1939·0	1939 May 2·0	(5)
3·30	185·1577	334·7674	12·3511	1950·0	1941 Feb. 15·0	(4)
6·59	171·8110	196·2379	30·7291	1946·0	1946 Sept. 17·0	(2)
3·30	185·1902	334·7432	12·3513	1950·0	1947 Oct. 22·0	(4)
7·48	348·9042	2·3412	12·5132	1950·0	1948 Sept. 6·0	(6)
7·28	215·2968	167·3944	6·1530	1950·0	1949 Sept. 1·0	(7)
3·30	185·2108	334·7398	12·3805	1950·0	1951 Feb. 3·0	(4)
5·48	37·9425	165·6358	13·7930	1950·0	1951 May 9·0	(8)
6·12	170·2266	94·4012	21·6809	1950·0	1951 Aug. 22·0	(9)
4·90	356·3294	215·4232	17·6349	1950·0	1952 Mar. 9·0	(10)
..	73·8685	320·7365	123·9155	1955·0	..	(11)
3·30	185·1991	334·7460	12·3740	1950·0	1954 May 18·0	(4)
..	194·3992	2·3707	53·2152	1954·0	..	(12)
7·01	341·8910	145·6200	16·5762	1955·0	..	(13)
353·3	32·5058	48·3129	86·4992	1955·0	..	(14)
..	13·2312	303·8941	50·1279	1955·0	..	(15)
..	348·1850	338·7898	107·5032	1955·0	..	(16)
6·47	167·7804	242·5630	15·8799	1950·0	1955 Sept. 30·0	(17)
7·42	190·4521	188·5232	10·2490	1950·0	1954 Sept. 15·0	(18)
..	57·3332	72·2549	79·6251	1955·0	..	(19)
7·51	349·0793	2·3024	12·4922	1950·0	..	(20 a)
7·51	349·0818	2·3022	12·4920	1950·0	1956 Mar. 28·0	(20 b)

(11) Comet Abell 1955 b. L. E. Cunningham, *UAIC* 1506, 1516. Improved elements using observations covering 27 days.

(12) Comet Abell, 1953 g. S. Kanda, *UAIC* 1513. From observations 1953 October 20 to 1954 July 24.

(13) Comet P/Harrington–Abell, 1955 a, L. E. Cunningham, *UAIC* 1497. From 3 observations, arc of 8 days.

(14) Comet Mrkos 1955 e. G. Merton, *MS*. Improved elements from 4 pairs of Lick observations, arc of 84 days. The elements are very similar to those of comet 1707.

(15) Comet Bakharev–Macfarlane–Krienke, 1955 f. A. Dubiago, *UAIC* 1519. Based on 12 observations covering 15 days.

(16) Comet Honda 1955 g. I. Haségawa, *UAIC* 1518. From 3 observations July 30·8, August 10·8 and 14·7.

(17) Comet P/Perrine–Mrkos 1955 i. H. Hirose, *UAIC* 1534. Linking 4 observations of 1955 with 4 normal places of the 1909 apparition, including perturbations by Jupiter.

(18) Comet P/Whipple 1955 d. C. Dinwoodie, *B.A.A. Handbook* 1955. Predicted orbit.

(19) Comet Haro–Chavira 1954 k. G. Merton, *UAIC* 1542. Using 4 pairs of observations at Lick, January 13 to September 28. Residuals for the two middle places average 7″.

(20) Comet P/Ashbrook–Jackson 1955 c. (*a*) W. E. Beart, (*b*) M. P. Candy, *UAIC* 1487. Observations indicate T = April 6·17.

Additional notes

Individual Comets

1925 I P/Wolf (2). Antoni Przybylski: "Definitive orbit of Comet 1925 I (Wolf 2)", *Acta Astronomica*, Ser. c, **5**, 178, 1955. The elements he finally adopted were given in the Report for 1953 (*M.N.*, **114**, 368, 1954, ref. 2). This comet was at first designated 1924 IV. Identity with 1952 II (P/Harrington) has been suggested, but Przybylski thinks it unlikely.

1925 III Reid. Stefan Wierzbiński: "Orbite définitive de la comète 1925 III (Reid)", *Contrib. Wroclaw Astr. Obs.*, No. 10, 1955. The elements were given in the Report for 1953 (*M.N.*, **114**, 368, 1954, ref. 3).

1925 VII O. N. Barteneva. "Determination of the original orbit of comet 1925 VII (Shajn–Comas Solá)", *Bull. Inst. Theor. Astr.* **6**, (No. 4) 249, 1955. Uses Makower's method (see below) for this comet from $v=-150°$ to $+150°$ (i.e. 1885 to 1966) for determining the perturbations in $1/a$. At both ends of the range the orbit was slightly elliptical; $1/a=+0{\cdot}00007$ and $+0{\cdot}00020$ respectively.

1953 h Pajdusakova. Three pre-discovery positions found on asteroid plates taken 1953 November 7 at Tokyo are given in *UAIC* 1544.

Investigations into other cometary orbits are being made as follows: P/Halley by M. Kamienski; P/Arend–Rigaux and van Gent 1944 IV by A. Przybylski; P/Arend 1951 X by Sh. U. Kan; P/Kopff by F. Kepinski; P/Neujmin I by H. A. Randsaar; P/Oterma by A. V. Fokin; P/Taylor 1916 I by O. A. Sizova; van Gent 1941 VIII by A. M. Leiken. The results of other investigations by computers in the U.S.S.R. are given in the Table of Elements.

General

C. Whitney. "Comet outbursts." *Ap. J.*, **122**, No. 1, 1955 July.

S. G. Makower. "On the determination of the original orbits of long-period comets", *Bull. Inst. Theor. Astr.* (*Leningrad*) **6**, (No. 4), 244, 1955. The method uses the true anomaly as the independent variable in determining perturbations.

A number of papers of theoretical interest are to be found in Russian publications, notably *Ast. J.* (*U.S.S.R.*) Vol. 32, and *Pub. Ast. Obs. Stalinabad*, Vols. XX (1954) and (V) XXXVIII, 1955.

Corrigenda

112, 343, 1952. Comet Hubble 1936 V. In column headed Ω, for 96·9441 read 96·9496. See *J. des O.*, XXXV, 120, 1952.

113, 390, 1953. The elements ω, Ω, i for P/Schwassmann–Wachmann (2) are here referred to the equator. The ecliptic elements are reprinted in the Table above, ref. (3).

115, 196, 1955. ref. (7). Comet 1950 VI, for P/Wolf (2) in the Table, read P/Wolf (1).

115, 197, 1955. ref. (15). The observed value of T in the note should be corrected to $T=$August 13·5050.

J. G. PORTER.

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE GOLD MEDAL TO PROFESSOR THOMAS GEORGE COWLING

Professor Sir Harold Jeffreys

At the January meeting the Council awarded the Gold Medal of the Society to Professor Cowling for his distinguished contributions to theoretical astrophysics and particularly for his work on the stability of stars.

Cowling's main fields of interest have been Cosmic Electrodynamics and the Theory of Stellar Structure. In both fields he has made outstanding contributions, and his work is characterized by thoroughness and authority.

In Cosmic Electrodynamics his contributions have been largely of a critical nature: there can be little doubt that he did much to stem the flow of facile and fallacious papers that began to appear about the middle twenties, and his work greatly influenced the subsequent development of the subject.

His great critical powers were shown in his first published paper (*M.N.*, **90,** 140, 1929) in which he demonstrated by thermodynamical arguments that Chapman's theory of the then supposed radial limitation of the solar magnetic field was untenable. In a later paper (*M.N.*, **92,** 407, 1932) he discussed very thoroughly by the methods of the kinetic theory of gases the diamagnetism and drift currents to be expected in the solar magnetic field when a magnetic field is present. He showed that in thermodynamical equilibrium no such net effects could be expected and that further attempts to develop diamagnetic or drift-current theories of the radial limitation of the solar magnetic field or of geomagnetic solar and lunar diurnal variations were bound to be abortive. Meanwhile he calculated by the methods of the kinetic theory of gases the electrical conductivity of ionized gases in the presence of a magnetic field (*M.N.*, **93,** 90, 1932). In this paper he also drew attention to the fact that the conductivity transverse to the magnetic field would be restored to its ordinary value in the absence of the field if the Hall current flow is inhibited. These calculations were further improved in a later paper (*Proc. Roy. Soc.* A, **183,** 453, 1954) in which a number of applications to the solar atmosphere and terrestrial ionosphere were made. This later paper has become a classic in the subject.

The magnetic field of sunspots has also been the subject of several papers by Cowling. In the first of a series (*M.N.*, **94,** 39, 1933) he gave the now classical theorem that the generation of a magnetic field by motion of a conducting fluid is an impossibility in an axially symmetric magnetic field. He thereby demolished Larmor's dynamo theory of sunspot fields and greatly influenced subsequent work on the dynamo theory of the Earth's field. He added to his criticism the suggestion that sunspot magnetic fields might be the result of a deeper lying magnetic field convected to the surface of the Sun. In a later paper he showed (*M.N.*, **96,** 15, 1935) that contrary to the then current ideas on the cause of spot darkening, matter immediately below a sunspot would have to be moving *downwards* to produce the observed darkening. Later (*M.N.*, **106,** 218, 1946) he showed that sunspot magnetic fields could not be developed *in situ*, but must have existed before and after the visible lifetime of a spot. Cowling also criticized Alfven's theory of sunspots: he showed that the theory was inconsistent in several important respects.

Cowling had earlier considered the origin of the solar magnetic field. After dismissing as unlikely theories based on the thermal effects due to convection in a rotating Sun and on thermoelectric currents magnified by dynamo action, Cowling showed that a general solar magnetic field would decay through electrical resistance in a time of the order of the age of the universe. Cowling therefore suggested that the solar magnetic field might be a relic of a different primeval state (*M.N.*, **105,** 166, 1945). Cowling also considered the reversal of magnetic polarities observed in certain stars (*e.g.* HD 125248). He showed (*M.N.*, **112,** 527, 1952) that theories based on oscillations of the stars in a permanent magnetic field were unlikely to prove correct. He has also written on the subject of galactic magnetic fields, and an excellent expository article has recently appeared in *The Sun*, edited by G. P. Kuiper, entitled " Solar Electrodynamics ".

Cowling's most important work in Astrophysics, however, has been in the theory of stellar structure. His first paper on the subject (*M.N.*, **91,** 92, 1930) related to the so-called " point-source model " of a star. He concluded that it was impossible to derive evidence about a " mass-luminosity " law from such a model—a result which was of considerable interest at a time when Eddington and Milne were arguing about the validity of this law. In a later paper (*M.N.*, **91,** 472, 1931) he showed that the suggestion made by Milne about the fitting of polytropic models in his theory of stellar structure was incorrect. Much the same conclusion was reached independently by B. Strömgren at the same time.

This paper was followed by one which has become a classic in the theory of stellar structure (*M.N.*, **94,** 768, 1934). The problem of the stability of a gaseous star had been considered by Eddington and Jeans. In Jeans's discussion a fundamental assumption was made concerning the displacement of a gas particle from its equilibrium position, thereby reducing the problem from one of an infinite number of degrees of freedom to one of just a single degree of freedom. The result of this assumption was shown by Cowling in this paper to place too great a restriction on the conditions for vibrational stability. In later papers (*M.N.*, **96,** 42, 1935 and **98,** 528, 1938) he showed that under certain conditions a star would possess a convective core fitting on to a radiative envelope. This model, now known as Cowling's model, has been the starting point of much subsequent work on stellar structure and evolution. He has also discussed the luminosity and stability of completely convective stars, arriving at more stringent conditions for stability which may be violated at certain later stages of stellar evolution where large convective zones may be important.

Two other papers on stellar structure may be mentioned: one on the apsidal motion of binary stars (*M.N.*, **98,** 734, 1938) which provided further evidence for the fact that the density concentration of the stars was in closer agreement with Eddington's theory than with the results of H. N. Russell. The other paper (*M.N.*, **101,** 367, 1942) removed the restriction made in the 1934 paper on the stability of gaseous stars, namely, that the oscillations were radial. The discussion related to polytropic stars and the paper was chiefly concerned with tidal oscillations.

Finally, Cowling collaborated with Chapman on a book on gases (*The mathematical theory of non-uniform gases*) published by the Cambridge University Press. This is universally recognized as the standard work on the subject.

AN ADDRESS BY THE PRESIDENT

THE EARTH'S THERMAL HISTORY

Professor Sir Harold Jeffreys

It has been suggested to me that I should choose a geophysical subject for this address, but I have selected one with an intimate contact with astronomy. When I first became interested in astronomy it was generally believed by astronomers that the planets came into existence by some sort of contraction out of a gaseous nebula and consequently were originally gaseous, and passed through a liquid stage in cooling. Various alternatives however existed, notably the Meteoritic hypothesis of Lockyer and du Ligondès, and the Planetesimal Hypothesis of Chamberlin and Moulton, which supposed that the planets were formed by accretion of solid particles or at least that their masses grew greatly in this way after they were formed. Some supporters of these alternatives maintained that the Earth has always been a cold solid body.

I am not going to develop the later history of cosmogonic theories now; I shall only say that I did so in my Bakerian Lecture to the Royal Society a few years ago (1), and that I see no ground for changing the main opinion I expressed there, that I see profound difficulties in every existing hypothesis on the origin of the Solar System. The most hopeful, I think, is that of K. E. Edgeworth, but it needs much more development, which would certainly be mathematically very difficult.

Nevertheless, every theory that fails helps us to the extent that the failure limits our range of guessing; or, at least, it would if people remembered how theories have failed. Unfortunately they do not always do so. What can also happen is that a mistaken objection to a hypothesis may be repeated again and again after the mistake has been pointed out.

This remark is particularly relevant to the thermal contraction of mountain formation. This used to be illustrated by the example of the shrivelled apple. The pulp contracts through loss of water, and the skin puckers so as to continue to fit it. But this illustration is unfortunate and is responsible for a great deal of misunderstanding. The essential feature of mountains is the presence of enormous fractures. We can see faults where the rocks on one side have been displaced up or down by thousands of feet relative to the other. In addition there are horizontal displacements of several miles, but it takes detailed mapping to demonstrate this. The skin of a shrivelled apple is not broken; it is a case of what is called elastic instability or, shortly, buckling.

This is most easily illustrated by pressing a postcard from end to end. With a gentle thrust nothing visible happens; with a greater one the card bulges into a wide curve. But it is not broken. That is elastic instability. Under sufficient force the flat form becomes unstable and a bent form branches from it. If we tried the same experiment with a glass plate of the same dimensions, it would take a much larger force to produce any visible effect, and when it did, the plate would not bulge but shatter. We could get elastic instability if the plate was thin enough. The crucial point is: in what conditions does fracture occur before elastic instability and when does the opposite occur? The problem is of great importance in engineering; either phenomenon will result

in the ruin of a structure, and it would be fatal to use the criterion for the wrong one. With most materials (not such as rubber) a necessary condition for buckling to occur before fracture is that at least one dimension across the direction of thrust shall be small compared with that along it. We cannot buckle a uniform sphere or cube. We can buckle a thin spherical or cylindrical shell, provided it is thin enough. But in geological conditions there is a further complication from gravity, which always resists departure from symmetry and hence makes for stability. The result for materials with the properties of crustal rocks, under the type of stress that internal contraction can produce, is that fracture will always occur first if there is anywhere a coherent layer more than about 10 metres thick (**2**, p. 313). As there certainly is, elastic instability cannot be of importance in major geological processes.

Then why do I waste your time by discussing it? The reason is that every now and again somebody does an experiment purporting to show that deformation due to internal contraction would produce a general wrinkled pattern, and nothing like actual mountain chains forming localized strips. When such a pattern occurs it is symptomatic of elastic instability, which is quite easy to produce on a small scale. I need only refer to the shrivelled apple again. In a stable body, on the other hand, fracture would occur first, and when fracture starts at one place it extends rapidly, roughly maintaining its direction until the greater part of the stresses are relieved. For example, it is easy to see that if we have two folds, one running round the equator from 90° W to 90° E through 0° E, the other from the north to the south pole in longitude 180°, every great circle will intersect both of these folds, and all great circles will be shortened by comparable amounts. Similar distortions would be produced by internal contraction in the Earth, and are sufficiently like what happened in the last great period of mountain formation, which produced one great system extending from the Pyrenees through the Alps and Himalayas to Eastern Asia, and the other along the whole west coast of North and South America. Further, if there is progressive internal contraction, the stresses begin to grow again after each major upheaval, and there will be an apparently quiet period until they become great enough to produce a new set of fractures; this agrees with the fact that mountain formation is intermittent. Fracture is commonly associated with plastic flow, and there are also great folds in mountains. But plastic flow and fractures are similar in that they both start at a certain value of the shearing stress, and up to a point they can be considered together.

What could produce the contraction? One explanation is thermal contraction, which requires that the interior is steadily cooling. But doubts cast on the adequacy of thermal contraction for the purpose have led to alternative suggestions. One is change of state; this might be either a chemical change, recrystallization, or atomic change. However, any change of volume arising in this way would lead to a release of latent heat, which would have to be conducted away, and the effect would be substantially the same as that of a specially high coefficient of thermal expansion at a particular temperature. So I think that any such suggestion should best be regarded as a modification of the thermal contraction theory rather than something fundamentally distinct. None of them, so far as I know, has been put in a sufficiently definite form to permit quantitative test. One fundamentally distinct alternative is that the

Earth was formed by accretion in such a way as to leave it thoroughly porous. Then the closing of the pores by compression would give a contraction. But this is unsatisfactory in two respects. First, the stresses at a depth of a few kilometres would suffice to close up the pores, and one or two kilometres of contraction is as much as could be expected. Secondly, the outside would in any case be the least compacted part, and compaction at greater depths could not produce more compression of the surface that it could take up by slipping of the grains over one another. Dr G. M. Lees, in a recent address to the Geological Society (**3**), suggested that the Earth might have originally been some 1000 km or so greater in radius than at present. This would imply that all but the crust was largely gaseous, and the crust would have collapsed into the interior at the first fracture.

Accordingly I see no hope of an explanation of mountain formation except by thermal contraction, which seems qualitatively satisfactory. Quantitatively, we are hampered by uncertainties in the data. My estimate in " The Earth " is that it could produce about 400 km of shortening of each great circle, and that each mountain system needed about 50 km. Thus there seems to be enough contraction available to produce about 8 major epochs of mountain formation in the last 1600 million years. Anyhow the result is of the right order of magnitude.

I should mention the various convection theories. These assume generation of heat within the shell of sufficient amount to produce circulatory currents. They depend, however, on the hypothesis of a finite viscosity at any stress, however small, so that, under long-continued stresses, the material behaves like a liquid. I believe this to be wholly inadmissible. In the first place, we know from seismology that the Earth's shell (reaching nearly halfway to the centre) has a considerable rigidity, increasing with depth. The correlation between rigidity for short period disturbances and strength for long continued ones is admittedly imperfect. But there is abundant laboratory evidence that for materials of large rigidity flow becomes appreciable only under a large shearing stress. It most definitely does not follow any law that says that rate of flow is proportional to stress however small the stress may be. Such an assumption has no laboratory data behind it. It might be true under a suitable combination of high temperature and pressure, but evidence for it can come only from the Earth itself. It is claimed that there is such evidence from the so-called post-glacial uplift in Scandinavia and Canada. The argument is that during the glacial period the weight of the ice made the subcrustal material flow out, so that the rocky surface sank; and since the ice melted there has been an inflow, making the surface rise again. By itself the argument looks plausible. But it contains the implicit assumption that every rise or sinking of the land is due to change of surface load. There is abundant evidence that this is false. A famous example is that of Pozzuoli in Southern Italy, where marks on the pillars of a temple show that the land has sunk about 20 feet, becoming submerged, and risen again since Roman times; but the change of surface load is negligible (**4**). Examples on a much larger scale are well known to geologists. Wales sank by about 35 000 feet while the Palaeozoic deposits were laid down; the bottom went down, displacing heavy stuff from below, while lighter sediments were deposited on top. Thus the mass per unit area was decreasing and the crust was sinking at the same time.

Such anomalous behaviour could arise from local differences of the rate of cooling in a solid, but to get it in a material of finite viscosity is like making water flow uphill. The argument from the Scandinavian uplift is simply a selection of one fact to fit a hypothesis, while all that do not favour it are disregarded. We can get vertical movement in a liquid; what I am objecting to is the naïve assumption that it is easier to produce long-continued vertical displacement in a liquid than in a solid.

It has long been known that the radio-activity of about 15 km of normal surface rocks would suffice to supply all the heat being conducted to the surface. If the average amount throughout the Earth was equal to that of surface rocks, it would heat up the whole interior till it became thoroughly liquid, and this would take about 10^7 years. Incidentally the Earth would move under tidal forces as much as the sea would, and we could detect no ocean tides. There is confirmation from seismology that there is a change of properties at a depth of this order (15 km) and the geological indications are that we can interpret it as due to rocks of roughly the properties of granite, containing pure silica and trisilicates, overlying something like dunite, which is mainly the orthosilicate olivine. In actual rock specimens the radio-activity is strongly associated with silica content. So it appears that the radio-activity is practically confined to a thin surface layer, and consequently heat generated by it takes a comparatively short time to get out and does not prevent cooling of the interior.

How could such a state of affairs arise? It presented a great difficulty for a long time, but the problem seems to have been solved by ideas of A. Harker, V. M. Goldschmidt and N. L. Bowen. L. H. Adams pointed out that a molten mass of silicates would solidify from the bottom up. The first crystals to form would be those of the substance with the highest melting point, in this case olivine. This would sink to the bottom, and thus any substances not capable of being fitted into an olivine crystal lattice would stay in solution until the residual liquid became so rich in other substances that new minerals would crystallize. Goldschmidt noticed that the atoms of the radio-active elements are so large that they could not fit into any silicate lattice whatever, and consequently must remain in solution to the last. This is confirmed by the fact that even in the granites they are concentrated on cleavage planes and on the interfaces between crystals, not inside the crystals. Bowen similarly attributed concentration of the more acidic minerals upwards to progressive crystallization of the less fusible, which happen on the whole to be also the densest. Thus a formerly fluid Earth leads quite naturally to an explanation of how the acidic rocks came to be concentrated to the top and to contain nearly all the radio-activity.

On the other hand there is the theory that the Earth grew by accretion of solid particles. I have no objection to accretion in its proper place, but some forms of it that have been proposed meet with a fatal objection. I gave this long ago in relation to the original forms of the Planetesimal Hypothesis, but proposers of some modern variants seem to have forgotten it. Suppose that a planet is growing by picking up smaller bodies. The frequency of a collision is nearly proportional to its surface area. But the smaller bodies can collide among themselves, with a frequency proportional to their total area. If there were enough of them to have a mass comparable with that of the planet, they would have a much larger total surface, and they would collide among themselves

and either volatilize or shatter one another long before the planet could grow appreciably. Accordingly I think that any idea that a large fraction of any planetary mass is due to direct accretion of solid particles is out of the question.

Nevertheless I think the matter has further interest. First, if the particles volatilized one another, I originally thought that they would stay volatilized. However, A. L. Parson has shown that if the solar system at its present temperature was filled by gaseous material with the mass and composition of the planets, the density would be far above the saturation vapour densities of silicates and iron. So the gas would proceed to recondense as dust, and it remains possible that there might be substantial accretion in the form of dust that may have volatilized and recondensed many times before being finally captured by a planet. This meets a major difficulty, since bodies less than some size between those of Ceres and the Moon could not have held themselves together in a gaseous state, and must have been solid from the start. Values of saturation vapour pressures, extending Parson's results, are given much more fully by Urey (**5**).

The other point is that the particles might not volatilize but merely shatter one another. There is an old idea that meteorites may be bits of an exploded asteroid. This has some support from their appearance. They contain large crystals, and this suggests very strongly that they are parts of a larger body that cooled slowly from a liquid state. It has been very difficult to think of an adequate mechanism for explosion, but fracture by impact may be possible.

Now the question arises what sort of internal temperature could be reached by a body growing by picking up dust. Energy liberated by impact would be radiated away rapidly and would hardly affect the internal temperature. But the gravitational energy, if it could be retained, would suffice to produce temperatures of the order of 10^4 degrees. Conflicting estimates exist of the temperature likely to be actually reached. It appears possible that the central temperature might in suitable conditions reach the melting point; it would certainly attain at least that due to adiabatic compression, which might be about 1000 degrees.

In the absence of a satisfactory theory of the origin of the solar system, it appears that we cannot say whether the Earth was originally fluid or not. But the upward concentration of the acid rocks and the radio-active elements is very strong evidence that it was fluid at some time. I should mention that some petrologists have said that the separation could not be so thorough as I have supposed, and that granite could not separate out of a magma consisting mainly of orthosilicates. (For discussion, see Bowen (**6**).) I am not sure, however, that they have adequately considered the consequences of having a depth of 3000 km of material for the fractionation. The alternative would apparently be that the outer layer was plastered on the outside during the passage of the solar system through a region of space where it picked up matter of a highly abnormal composition. This seems much less likely. There are arguments on the loss of material from the Earth if it was once fluid. Kuhn and Rittmann have argued that diffusion is so slow that if the Earth had a solar origin it would have retained nearly all its hydrogen, and the core at least would be mainly hydrogen (and they are willing to believe this). They have missed the importance of convection in a liquid, which would bring volatile matter to the surface and dispose of it at a rate comparable with that of the loss of heat;

for transfer of heat and diffusion by turbulence are parts of the same process. There are strong geophysical arguments against the large hydrogen content that they require, but their papers have historical importance in so far as they have led to the study by Dutch workers (**7**), of the properties of hydrogen at high pressures and to W. H. Ramsey's (**8**) application to the outer planets. On the other hand Urey (**9**) maintains that a fluid Earth would have lost not only hydrogen but carbon and nitrogen too. The point is important, but carbon and nitrogen are probably confined to the neighbourhood of the surface and might have been added later.

Supposing that the Earth was originally solid, is it possible that it could have melted and then proceeded to cool again ? I think that there is no doubt that it could. If the present radio-active matter was uniformly distributed through a cold Earth without change of its total amount it would heat the interior to melting in something like 3×10^9 years. But this is an understatement. The average life of an ordinary uranium atom is about 7×10^9 years. That of the isotope ^{235}U is about 10^9 years. 5×10^9 years ago, it would have been as abundant as ordinary uranium. The radio-active isotope of potassium, ^{40}K, has an average life of about 2×10^9 years. Until recently we have not needed to consider possible ages of the Earth exceeding 2×10^9 years, but discoveries of older and older rocks have shown that something like $3{\cdot}5 \times 10^9$ years is probable. Ordinary uranium and thorium would be more abundant than now, but the additional heating due to the larger amounts of ^{235}U and ^{40}K was probably more important. Thus it is probable that if the composition was originally uniform, melting would start in something between 10^9 and 2×10^9 years and that the oldest rocks were made while the Earth was heating up. But melting would start on interfaces between crystals, and we should again have the settling of crystals to the bottom, and the magma would be forced up just as in the solidification of a fluid Earth. Cooling would become possible as the radio-active elements with short lives disintegrated. The difference would be that the heat could be lost by conduction to the surface when the thickness of the solid crust reached about 50 km. Apparently this would leave the radio-active elements and the granite constituents buried at that depth, and this is no use to us in explaining the concentration near the surface. However, the initial expansion would produce a tension in the crust, and if the crust broke there would be a possibility of wide spread outflows, which it is tempting to identify with the continents. I do not wish to insist on this mechanism, except to say that the final results from an initially liquid Earth and an initially cold one might not be very different, and it is not obvious that an initially cold Earth is inconsistent with a thermal contraction theory.

Two major modifications of the thermal contraction theory have been made recently by A. L. Hales (**10**) and J. Tuzo Wilson (**11**). The mathematics of the theory was given by C. Davison and Sir G. H. Darwin at a time when the crust of the Earth was still widely supposed to be only about 30 km thick, the rest being liquid. With cooling from the surface there is a layer of most rapid cooling; this has to be stretched horizontally to fit the less cooled interior. In doing so it shortens vertically and consequently the outer surface is too long to fit it, since the outer surface has already done all the cooling it can. The resulting compression of the surface is available for mountain formation. This mechanism supposes that the body remains spherical till the last moment,

and would be just the same if everything but the outermost skin was liquid. But we now know that the Earth is solid halfway to the centre, and from the existence of deep focus earthquakes we know that elastic failure is mainly by fracture to a depth of about 700 km. This is about the depth of the layer of most rapid cooling. So it seems that the adjustment of size at these intermediate depths takes place by fracture at about 45° to the greatest principal stress. This will have the effect that most of the material is displaced elastically, but there will be great faults extending up to the surface. Between them the material sinks in, and we have an explanation of rift valleys. The surface rocks, already too long to fit the interior, are pulled sideways. Thus effectively most of the extension inferred in the intermediate zone is added to the compression of the outer crust, and the available compression is multiplied several times.

Hales actually gets a total crustal shortening not very different from my value obtained by following Darwin. This is because he has used a much smaller coefficient of thermal expansion. I am not sure which is right in the conditions considered.

Wilson starts from an old paper of P. Lake on island arcs. Lake noticed that the island arcs that stretch from the Aleutian Islands to Formosa are very nearly parts of circles and thought they represented the intersections of planes of fracture with the surface of the Earth. But the planes could equally well be replaced by cones with their axes vertical and their vertices at any depth. Wilson and Scheidegger associate this with the fact that deep focus earthquakes mostly lie on inclined sheets, the shallow earthquakes being in the outer edge of the sheets. It appears that the island arcs may represent cones of fracture. Their radii of curvature are of the order of 500 km, which is reasonable. A single cone, however, could not relax a general stress over the whole crust, and they think that the result would not be a single cone but a succession of cones with their vertices roughly along a great circle. They are able to trace such an arcuate structure in several great mountain systems. In some cases this is not obvious to the eye, but I think it is in the great curve of the Alps.

Wilson and Hales both discuss many other matters in much greater detail than can be mentioned here. Their work is completely independent, but I think consistent.

The origin of continents is a difficult problem. They imply great departures from a hydrostatic state, and it seems clear that they could not have arisen while the Earth was highly fluid. It seems equally clear that they could not have arisen after the shell became solid. This restricts us to events taking place during solidification. It is at this stage that we can legitimately appeal to consequences of a finite viscosity. Some years ago G. F. S. Hills called attention to a phenomenon in the boiling of jam, where the scum tends to collect in patches instead of being spread uniformly over the surface. This is a case of instability of a fluid heated below, which has now a great literature. Some years ago Miss M. E. M. Bland and I (**12**) investigated this problem for a viscous sphere, and it appeared that the easiest disturbance to excite would be one where currents sweep through the centre and return over the outside. With crystals condensing in the meantime this looks like providing an explanation of the land and water hemispheres. I later (**13**) investigated the effect of a liquid core (which has since been more accurately treated by Chandrasekhar (**14**)); this introduced some complications but it looked as if the main result would stand.

However it seems likely that this problem is too simple for direct application. The composition of the shell is such that a granitic layer could separate out only at a late stage, and we ought to consider instability in a medium consisting mainly of crystals settling into a fluid magma (what was called a sludge theory in our paper). Instability can occur in waterlogged sediments; I need only mention the pools of water that sometimes appear on extended tracts of wet sand; so the separation in patches is possible in suitable conditions. There are, I think, too many unknowns in this problem for it to be studied usefully at present, but it should not be forgotten.

In conclusion, I do not say that the thermal contraction theory is wholly satisfactory. There are so many uncertainties in the data, particularly the coefficient of expansion and the thermal conductivity, that it would be optimistic to say that we know either the theoretical or the observed values within a factor of 2. What I do say is that the theory gives an agreement in order of magnitude, and I see no reason to believe that any alternative theory does so, or even that any will account qualitatively for the major facts of geology.

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